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OBSERVATIONS

ON THE

LIMBS OF VERTEBRATE ANIMALS:

THE PLAN OF THEIR CONSTRUCTION;

THEIR HOMOLOGY;

AND

THE COMPARISON OF THE FORE AND HIND LIMBS.

(*Communications to the Cambridge Philosophical Society.*)

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THE chief purpose of the following Observations is, first, to point out the principles on which a COMPARISON of the Fore and the Hind Limbs may be satisfactorily made; and, secondly, to offer some suggestions with regard to the HOMOLOGY of the Limbs. Both these are controversial subjects; and they are both of interest to the philosophical student of Human Anatomy no less than to the Comparative Anatomist.

An account of the limbs of vertebrate animals is prefixed, indicating the general plan of their construction and their chief modifications; and, in the appended Tables, the correspondence of the several Bones, Ligaments, Muscles, Arteries, and Nerves of the Two Limbs, in Man, is shown in accordance with the principles above mentioned.

G. M. HUMPHRY.

CAMBRIDGE,
May 1, 1860.

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THE LIMBS OF VERTEBRATE ANIMALS.

Development of limbs in the animal series proportionate to their office as organs of locomotion.

Throughout the vertebrate kingdom, as a general rule, each animal has two pairs of limbs—an anterior and a posterior pair. The chief office of the limbs is to serve as organs of locomotion: and we find that their size and importance, in relation to the rest of the body, increase in proportion as this office is delegated to them. Thus in Fishes, where the weight is buoyed up in water, and where the tail is the great agent in propulsion, the limbs—represented by the pectoral and ventral fins—play a comparatively subordinate part, and are adapted to balance and guide, rather than to drive on, the animal. They are uncertain in their position; and, though they are sometimes broad and abundantly supplied with terminal elements, or fin-rays, they are always short, and are deficient in one, or more, of the proximal elements. This is especially true of the ventral fins; these, in some fishes (the Eel) are altogether wanting; in most fishes they are composed merely of rays or fingers attached to a bone, which is the representative of the pelvis; and they vary much in their position, being in the Carp near the tail, in the Perch attached to the bony framework of the shoulders, and in the Cod placed quite in front of the pectoral fins.—In the Whale also, where the tail is still the great agent in propelling the animal, there is only a trace of pelvis, the hinder limbs are deficient, and the fore limbs are small and imperfect, the bones of the arm and forearm being stunted and sometimes united, and the carpal bones often more or less imperfect or consolidated together.—The same principle is exhibited in the metamorphoses of the Tadpole of the Newt. The creature becomes fitted for movement upon land by the outgrowth, first of the anterior, and then of the posterior limbs; still the perfect Newt swims along in water, chiefly, by the lateral movements of its broad tail, and its limbs are accordingly small. In Lizards, which move habitually, and with more activity, upon land, the breadth of the tail is lessened, the limbs are larger and stronger, and the fore and hind limbs are nearly on a par, and perform a nearly equal share in supporting and moving the trunk. The Chelonian reptiles are constructed merely to crawl slowly along; hence although the tail is small the limbs are also short. In the Frog the tail is abortive; and the limbs, especially the hind limbs, undergo great development to enable the creature to take its powerful leaps. In Birds the tail serves rather to balance and guide the animal than to propel it; the movement in the air is chiefly effected by the anterior, and that upon the ground by the posterior, limbs. In Mammals, with few exceptions, the tail performs but an insignificant part in locomotion; the work of propulsion devolving, chiefly, upon the

hinder limbs, which are more developed than in the preceding classes, while the fore limbs are constructed, in great measure, to support the trunk. In MAN the tail is wanting; the whole work of supporting, as well of propelling, the trunk, is assigned to the hinder limbs, which are comparatively larger than in other animals; and the fore limbs are left free to perform a variety of other offices.

We perceive, therefore, as we ascend through the vertebrate series, that there is, generally speaking, a gradually increasing concentration of the locomotive functions; that, in the lowest members of the series, nearly the whole of the body is concerned in the work of propulsion, and the entire skeleton is constructed with reference to that lateral movement whereby the animal is driven through the water; whereas, in the higher orders, the work is performed chiefly by the limbs, and, more and more, by the hinder limbs; and that, in the highest member of the group, the office of locomotion is assigned entirely to the hinder limbs[1]. This is in accordance with the observation that the plan of "division of labour" is carried out most in the highest classes of animals; and it is an illustration of the principle that concentration and perfection of function usually go together.

Three segments of each limb.

Forasmuch as throughout the vertebrate series the limbs have one chief purpose to fulfil, so are they constructed upon one general plan. Each is composed of three chief segments—a proximal, a middle, and a distal; and each pair of limbs is appended by its proximal segment to a more or less complete bony arch, which, in the case of the fore limbs, is called the "scapular arch," and, in the case of the hinder limbs, the "pelvic arch." The distal segment is the most constant and the most important part of the limb, the other segments being subservient to it. It is composed of a considerable, and variable, number of pieces; of these, some, arranged in a radiating finger-like manner, are called rays, fingers or toes, and others, straighter and thicker, constitute the carpus or tarsus. The middle segment is composed of two bones; and these connect the carpus or tarsus of the distal segment with the single bone of which the proximal segment consists.

Number of components of segments.

In the more completely-formed limbs we observe a progressive and regular increase in the number of the components of the several parts, as the latter become more distant from the centre. Thus the proximal segment consists of one bone (*humerus* or *femur*). The middle segment consists of two bones (*radius* and *ulna* or *tibia* and *fibula*). The first series of the distal segment—that is, the first row of the carpus or tarsus—consists of three bones (*scaphoid*, *semilunar* and *cuneiform*, or *scaphoid*, *astragalus* and *os calcis*). The second series—the second row of the carpus or tarsus—consists of four bones (the *trapezium*, *trapezoides*, *magnum*, and *unciforme*, or the three *cuneiform* bones and the *cuboid*). The third series consists of five rays—the digits; of these, each is composed of a *metacarpal* or *metatarsal* bone and *phalanges*. An excellent illustration of the mode of construction of the distal segment of a limb is furnished by the paddle of a Plesiosaurus or an Ichthyosaurus, (Pl. III. fig. 7, 8, 9), the several parts being there reduced to their simplest forms.

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[1] The Cetaceans form an exception to the rule; inasmuch, as though, in their general features, they are assimilated to the higher orders, so as to be admitted into the mammalian class, yet their habitat renders it necessary that their locomotive apparatus should resemble that of fishes.

That deviations from this numerical arrangement exist in certain animals is no wonder, and is scarcely to be urged as an argument against a rule which will be found to hold good in so large a number of instances. Indeed the exceptions are, for the most part, of a kind which tend rather to confirm the rule[1].

DISTAL SEGMENT OF FORE LIMB.

Let us survey briefly some of the principal modifications of the limbs, beginning with the fore limb, and with its distal segment.

Human hand; In MAN this segment, being freed from the laborious duty of supporting or propelling the trunk, and being devoted to the higher office of ministering to the varied requirements of an intelligent being, exhibits a greater nicety of construction, as well as a greater range and variety in the movements of its component bones upon one another, than it does in any other animal. The two most characteristic features of the human hand are, first, that it is articulated with only one bone (the *radius*) of the forearm, a fibro-cartilage being interposed between the *cuneiform* bone and the *ulna*, so that the whole hand may revolve with the radius upon the ulna, freely and easily, in the movements of pronation and supination; secondly, that the Thumb is of large size, is divergent from the other fingers, and is capable of being moved so as to be an opponent to each of them.

its tripartite construction. The Hand presents an obvious tripartite division. The middle portion consists of the *semilunar* bone, the *os magnum* and the middle finger. The outer part consists of the *cuneiform* and *unciform* bones with the outer two fingers; and the inner part consists of the *scaphoid* bone, the *trapezium* and the *trapezoides* with the thumb and fore-finger. Thus the middle part remains single in its whole extent; whereas the outer and inner parts are again subdivided; and it will be observed (see diagram, Pl. I. fig. 3) that the subdivision of the inner part takes place in the second row of the carpus, and that of the outer part in the metacarpus.

Pisiform bone not a veritable element of the carpus. An omission of the PISIFORM bone in such an arrangement of the carpal bones is, I am aware, in opposition to the views of some eminent modern anatomists, and to the fact that this bone is very generally present in mammals, and that it is also present in some reptiles; and it is in these animals that the distal segments of the limbs are formed in the most regular and, as regards the number of bones, the most complete manner. Nevertheless, it is not always present even in these animals. Thus in most TORTOISES, although the carpus is in other respects well formed, the pisiform bone is absent; and in some it seems rather to result from a fission of the cuneiform than to form an essential separate element. In TURTLES it is shifted from the proximal to the distal carpal row. In some mammals also

[1] The progressive increase in the number of the segments of the limbs was remarked by Dugès, Mémoire sur la conformité organique dans l'échelle animale. *Annales des Sciences naturelles*, 1831, XXIV. 254. M. Gervais conceives that the five rays of which a limb properly consists, and which are usually distinct in the distal portion, are embodied in each of the proximal segments; for instance, that both the humerus, and the femur contain the representatives of five rays. Three of these he thinks are indicated by the Epiphyses at the ends of either bone; in the shaft they are blended into one: the other two rays he does not find it easy to trace. Comparaison des Membres chez les animaux vertebres. *Annales des Sciences naturelles*, 1853, XX. 59.

(Bradypus) it is absent or conjoined with the cuneiform, forming a process projecting into the palm. In no animal does it really enter into the composition of the carpus. It seems as reasonable to regard it as an offset from the carpus for the purpose of ministering to the flexor tendon, and as, therefore, partly analogous to the sesamoid bones, which are sometimes (Armadillo) developed alongside it, as to consider that it belongs to the true carpal bones. Moreover, that which is allowed to be the homologue of the pisiform bone in the hinder limb never remains as a distinct element, but always is, or becomes, conjoined with the bone (*os calcis*) corresponding with the *cuneiform*. An examination of the paddle of the Ichthyosaurus may suggest that the pisiform bone of the higher animals is the rudiment of an additional (or sixth) digit: but on the whole I am disposed to consider this bone to be, like the *patella*, developed in connexion with, and in relation to, the muscular system, though intimately related to the endo-skeleton, and to regard it as occupying an intermediate position between the *sesamoid* bones, which are always separate from the endo-skeleton, and the *processes*, such as the trochanters of the femur and the tubercles and inner condyle of the humerus, which, though formed from distinct nuclei, become united to the endo-skeleton.

In man the pisiform bone is articulated only with the cuneiform. In many other animals it is articulated also with the ulna. In some carnivora (Pl. II. fig. 28, 8) it is prolonged backwards and upwards, like the heel-bone, to give additional power to the flexor tendon. In the Chrysochloris Capensis (Cuvier, *Leçons d'Anat.* I. 387) it extends up to the internal condyle of the humerus; so that the forearm in that animal is composed of three bones instead of two.

Components of distal segment in lower animals sometimes more numerous than in man;

In the lower animals the number of bones forming the distal segment of the fore limb occasionally exceeds that in the human hand. Thus in the Fish the terminal rays may be multiplied to an almost indefinite amount; though there is no increase in the number of carpal bones. In no existing vertebrates, above fishes, does the number of digits exceed five. In Mammals, cetaceans excepted, the number of bones in each digit is restricted to four, including the metacarpal. In many Reptiles, however, (Alligators, Iguanas and even in some Tortoises as Emys Punctata) the number of phalanges in the second or third digits is increased to four or five, the additional ones being probably those next to the terminal phalanges. In some extinct reptiles (Plesiosaurus) the phalanges are still more numerous; and in the Ichthyosaurus the number of the digits appears to go on increasing with the age of the animal. In Chelonians the subdivision of the lateral parts of the carpus are, sometimes, more complete than in man; thus the *unciform* bone is often in two parts (Pl. II. figs. 23 and 25, 12, so also in some Lizards, fig. 24); and not unfrequently this is the case with the *scaphoid* (fig. 23, 5). In the wrists of some Quadrumana and Rodentia is an additional bone, which may be regarded as resulting from a division of the scaphoid; and in the Mole a supernumerary ossicle is added on the radial side of the carpus for the purpose of increasing the scraping power of the hand.

are commonly fewer.

Far more commonly, however, the number of bones is less than in the human hand. In some the number of *carpal* bones is diminished. Thus in Carnivora and many other animals, the *scaphoid* and *semilunar* are united, forming the *scapho-lunar* bone (Pl. II. figs. 30 and 36). In the Armadillo, and certain Chelonians (fig. 25), the *trapezium* and *trapezoides* are one bone; and in the Crocodile (fig. 32) the number is still further

reduced. In the Dugong, not only are the *scaphoid* and *semi-lunar* united, but the several bones of the distal row are joined in one. This one, however, does not well sustain all the digits, inasmuch as the fifth metacarpal rests chiefly upon the *cuneiform*. In some the number of the *phalanges* is reduced in each finger; the subtraction in these instances being apparently made, like the addition in those just mentioned, immediately behind the terminal phalanx. Thus each of the digits in certain Chelonians (figs. 23 and 25), and in Bradypus (fig. 21), consists only of a proximal and a terminal phalanx, the intermediate bone being absent. In another class of cases the number of *digits* is reduced; and the gradations, which may be observed in this reduction, are peculiarly interesting, and have been pointed out, by Professor Owen[1], with his usual perspicuity.

Number of bones in Pollex;

The digit that is first found wanting is that which, even in the most perfect member, exhibits an incompleteness, namely, the inner one or pollex. Perhaps the principle of adhesion to rule in the construction of the animal frame has no better illustration than in the instance of the pollex, which, with scarcely an exception[2], contains only three bones. Even where, as in the Seal (Pl. II. fig. 18), it is prolonged beyond the other digits, this is effected, not by the addition of any bone, but by the elongation of its three components, and chiefly of the middle one.

the second phalanx missing.

The evidence afforded by the human hand[3] renders it probable that the second phalanx is the missing bone in the thumb; and this is confirmed by an examination of the paw of the Bear (fig. 36), the Seal, and other animals, and by the fact, just mentioned, that the second phalanx is sometimes wanting in the other digits as well as in the pollex.

Order of disappearance of Digits.

The disappearance of the digits may be traced in the following order. In Quadrumana, in many Carnivora, and in some other animals, the pollex retains the same number of bones as in man, but is short; in Plantigrades, however, the Bear more especially, it is relatively nearly or quite as long as in the human hand. In the Elephant (Pl. II. fig. 1) it consists of only two bones; viz. the metacarpal bone and the terminal phalanx. Nevertheless it attains nearly to the same length as the other digits of the forefoot, in consequence of the *trapezium* being prolonged so as to resemble, and take the usual place of, the *metacarpal* bone. In the Daman there is only one short tapering bone appended to the *trapezium;* and in the Hyæna (fig. 30), the Hog (fig. 37), the Cape Bear, the Hippopotamus (fig. 2), and others, the only vestige of the pollex is a small rounded bone, probably the *trapezium*, articulated with the *trapezoid.* In the Dugong also the pollex consists of only one short bone. In the Rhinoceros (fig. 3) digit v. is wanting, as well as the pollex, with the exception of a small bone articulated with the *cuboid;* this corresponds with the small representative of the pollex, which, as in the case of the Hippopotamus, remains appended to the *trapezoid.* In the fore-foot of the Rhinoceros, therefore, digits II. III. IV. only exist with mere vestiges of digits I. and v. Each of the three remaining digits has its particular bone in each row of the carpus: thus, No. II. is connected, by means of the *trapezoid* and the *scaphoid*, with

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[1] See also the *Leçons d'Anat. Comp.* 1835, I. 534.

[2] The inner digit of a Scincus in the Museum of this University (Pl. III. fig. 6) contains three bones besides the metacarpal; the corresponding digit in the hind limb of the same animal has only the usual number.

[3] See my *Treatise on the Human Skeleton*, p. 395.

the *radius;* No. IV. is connected, by means of the *unciform* and the *cuneiform*, with the *ulna*, and No. III. by means of the *os magnum* and the *os lunare*, with the radius and the ulna. The *pisiform* bone is still present as an appendage to the cuneiform bone.

We do not trace so gradual a disappearance of digit V. as of the pollex. Thus, though in the HIPPOPOTAMUS it is of full size, in the RHINOCEROS it is reduced to the rudiment just mentioned. In the CAPE BEAR, however, digit V. is comparatively short; and in that animal, in the ARMADILLO and ORNITHORHYNCHUS, the unciform bone is reduced in size, so that the metacarpal of this digit rests, as in the Dugong, upon the cuneiform bone.

Number in Ruminants,

In RUMINANTS (fig. 4) there are only two digits; and their metacarpals, though separate in the embryo, become soon united in their whole length. There is some difficulty in deciding to which of the three in the Rhinoceros these two digits of the ruminant correspond. *A priori* we should imagine that the digits II. and III. being the largest, would be the most enduring in the animal series; and some confirmation of this view is afforded by the presence of a small elongated bone upon the upper and posterior surface of the outer aspect of the double metacarpal in sheep and oxen, which we might readily suppose to be the rudiment of digit IV., as well as by the fact that the ulna is not prolonged to the wrist[1]. But, on the other hand, the outer part of the double metacarpal in all these animals rests upon the *cuboid* and the inner part upon the *os magnum;* and this suggests to Prof. Owen that the digits III. and IV. are the ones which are represented in the cloven foot of the ruminant. The correctness of this view gains countenance from the circumstance that in some ruminants (ELAPHII, fig. 5) a splinter-like metacarpal extends, on either side of the hinder surface of the double metacarpal, to the supplementary hoofs; and as these are evidently the representatives of digits II. and V., so must the large double metacarpal be the representative of digits III. and IV. Moreover, in the HOG (fig. 37) the pollex is wanting, with the exception of the rudimentary *trapezium,* and digits II. and V., though containing their proper complement of bones, are considerably shorter than Nos. III. and IV.

in Solidungula,

In SOLIDUNGULA (fig. 6) digit III. alone remains; and the splint-bones, extending down behind its metacarpal, are the rudiments of digits II. and IV. The tripartite construction is, however, still preserved in the carpus by the presence of three bones in each row, viz. the *cuboid, lunar,* and *scaphoid* in the proximal row, and the *unciform, magnum* and *trapezoid* in the distal row.

in the Sloth,

The digits of the THREE-TOED SLOTH (fig. 21) are Nos. II. III. IV.; and feeble representatives of Nos. I. and V. may be seen budding from the sides of Nos. II. and IV. There are also the three bones in each row of the carpus[2].

in Birds.

In the terminal segment of the BIRD's wing (fig. 34) the several parts are more confused, and it is not easy to refer them precisely to their respective homo-

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[1] Van der Hoeven says that Nos. II. and III. are the remaining digits in the RUMINANT.

[2] A modification is observable in the paddle of the WHALE (fig. 26). The *lunar* is the chief bone of the carpus. It is situate, as in the PLESIOSAURUS, beneath the space between the *radius* and the *ulna.* It bears the digits III. and IV. through the medium of the *os magnum* and the inner part of the *unciform.* The outer part of the latter bone, which is separate from the inner part, bears digit V.; and the *scaphoid* and *trapezoid* bear digit II. In this animal, therefore, the middle division of the distal segment of the limb consists of two digits, while each of the outer divisions is composed only of one, which is contrary to the arrangement usually observed.

types in the other classes; still there are three digits, which analogy leads us to suppose correspond with the three middle digits of the human hand. There is no sufficient reason to regard the inner one as a pollex, though that is often done. The three metacarpals are more or less united together, being usually ankylosed at their ends with interspaces between their shafts. There are two separate bones in the carpus; and it would look as though a third were blended with the upper end of the triple metacarpal. It is worthy of remark that in birds with short wings—the Cassowary and Ostrich, and in the Apteryx (Pl. I. fig. 10)—the distal segments are the least developed. The digits are very short, and are reduced to two or one; whereas the humerus, though short and small in comparison with the rest of the skeleton, is long and large in comparison with the bones of the other segments of the limb.

Relative shortness of distal segments in Struthionidæ.

In almost every one, therefore, of the many modifications which the distal segment undergoes in different animals we find the tripartite construction carried out in some part, and that usually the part nearest to the forearm. Of the three divisions the middle is usually the longest and the strongest, and it is also the most constant. Where great length and solidity are required it is projected beyond the others so as to form a firm pillar of support, as in Solidungula. Where great breadth is more suitable to the wants of the animal, the three divisions, as in the Rhinoceros, are of more equal size. Further, additional digits are often developed at the side of one or both of the lateral divisions; these constitute the little digit and the pollex. Hence digits I. and V. may be regarded as appendages to II. and IV. This view derives confirmation from the fact that these digits are usually carried upon the same carpal bones with Nos. II. and IV. They are, moreover, sometimes, as in the Sloth and Rhinoceros, mere rudimentary appendages to digits II. and IV.

The tripartite division usually observable.

THE MIDDLE SEGMENT OF THE FORE LIMB

Middle segment of fore limb;

in Reptiles,

consists of two bones—the *radius* and the *ulna.* The following arrangement is usually observed in Reptiles[1]. The two bones are, as a general rule, of nearly equal size, and of simple shape, and each contributes, in a nearly equal degree, to the formation of the elbow-joint and of the wrist. They descend in nearly parallel lines from the humerus to the carpus, the radius being in front of, or anterior and internal to, the ulna; and the part is more or less supine. The lower end of the radius is articulated with the *scaphoid*, and thus carries the inner division of the foot. The lower end of the ulna is articulated with the *cuneiform*, and thus carries the outer division of the foot; and the *lunar*, or proximal bone of the middle division of the foot, is articulated to both the radius and the ulna. The lunar is however, commonly, more closely connected with the ulna than with the radius, so as to connect the middle digit with the former bone rather than with the latter. In the Turtle (Pl. II. fig. 31, 5) the scaphoid is in two parts; the inner piece, which carries the trapezium and the pollex, is very small, and is carried by the radius, which also is comparatively small, and descends below the level of the ulna. All the other digits

[1] In the Frog there is but one bone in the forearm. It is, however, evidently the resultant of a fusion of the radius and ulna.

and carpal bones, including the trapezoid and the outer piece of the scaphoid, are carried upon the broad end of the ulna. In land TORTOISES, however, (fig. 25) the reverse rather obtains; inasmuch as the radius and the scaphoid are of larger size, and the scaphoid (5) is usually prolonged outwardly, beneath the lunar (6), between it and the os magnum (11), so as to connect the middle digit, as well the inner two digits, with the radius.

in Birds,

In BIRDS (fig. 34) the *ulna* is commonly larger than the *radius* in the whole length, and affords a more complete support to the carpus. Both bones are, however, united to the carpus by broad articular surfaces and are nearly parallel in their course. The radius and the radial edge of the carpus are turned forwards or upwards, so that the parts are in a position midway between pronation and supination.

in Monotremes,

In MONOTREMES the reptilian character is, to some degree, presented as regards the parallelism of the bones of the forearm, because the external condyle of the humerus looks forwards; and in the ORNITHORHYNCHUS it is so as regards the relation of the radius and the ulna to the components of the foot. In that animal (Pl. II. fig. 19) the inner division of the foot—digits I. and II. with the scaphoid portion of the scapho-lunar, the trapezium and trapezoid bones,—is connected with the radius; the outer division—digits IV. and V. with the unciform and cuneiform bones—is connected with the ulna; and the middle division—digit III., with the os magnum and the lunar portion of the scapho-lunar—is connected equally with both radius and ulna. In the ECHIDNA, however, and other mammals, the inner two divisions, including digits I. II. and III. if they exist, with their carpal bones, are carried by the radius; though in some (PACHYDERMS) the lunar has a slight articulation with the ulna.

in other Mammals.

In MAMMALS above monotremes the parallelism of the bones of the forearm is generally lost, the radius crossing the ulna more or less obliquely. This takes place because the condyle of the humerus, from which the radius runs, is, in these animals, placed on the outer side of the limb, while that division of the foot, with which the radius is especially connected, is internal, and the forefoot, or hand, is prone. Where great strength is required to bear weight, as in most PACHYDERMS and RUMINANTS, the parts are fixed in the state of pronation; and the radius is largely articulated with the carpus and encroaches over the whole, or nearly the whole, of the fore part of the articular surface of the humerus, thus throwing the ulna backward and rendering the two bones nearly parallel[1]. In SOLIDUNGULA, where the object is to combine fleetness with strength, the principle of consolidation is carried out, in the middle, as well as in the distal, segment of the limb, by the dwindling of the ulna almost to its olecranon portion; so that the radius forms the sole connecting medium between the humerus and the carpus.

Relation between disappearance of ulna and that of outer division of foot.

A relation may be observed between the disappearance of the *ulna* and that of the external division of the foot, which is the division more particularly connected with the ulna. Thus in QUADRUMANA, CARNIVORA, RODENTIA, and most PACHYDERMATA, the fourth and fifth toes are present and the ulna is of

[1] It will be perceived that the parallelism of the bones of the fore arm, in this case, is established by the upper end of the radius extending, across the elbow, to the inner condyle of the humerus; whereas in reptiles it is due to the outer condyle of the humerus presenting, more or less, forwards, as well as to the imperfect pronation of the segment, both which conditions combine to render the course of the radius less oblique than it is in mammals.

considerable size down to the carpus; in most it is articulated with the cuneiform bone and in some with the lunar and with the pisiform also. In RUMINANTS the fifth toe is absent and the fourth metacarpal is blended with the third; and in these animals the ulna is very small in its shaft and barely reaches the carpus, and the cuneiform, together with the other carpal bones, is articulated with the radius. In SOLIDUNGULA the middle digit only is present, and the ulna is reduced to its olecranon portion. It must be observed that, although these variations take place in the lower portion of the ulna,—or that which has relation to the distal segment of the limb,—the *olecranon* part,—or that which is subservient to the muscles moving the middle upon the proximal segment,—is of large, and of comparatively nearly uniform, size in all terrestrial mammals[1].

Range of pronation and supination in different animals.

The movements of the radius upon the ulna, giving rise to pronation and supination of the middle and distal segments of the limb, are most free in MAN; and they are provided for in him by the upper end of the radius being of circular shape and restricted to the outer condyle of the humerus, while a fibro-cartilage is interposed between the lower end of the ulna and the cuneiform bone, so as to allow the whole carpus to revolve with the radius upon the ulna. In the MONKEY the movement is less free; the upper end of the radius has lost the circular form, and extends into the space between the condyles of the humerus; and the cuneiform bone is articulated with the lower end of the ulna. In CARNIVORA the radius and ulna are more closely approximated in their whole length, and the radius encroaches still more upon the inner part of the articular surface of the humerus. In most PACHYDERMS, in RUMINANTS and SOLIPEDS, the radius extends quite across the articular surface of the humerus, is immoveable upon the ulna, and the tubercle for the biceps has disappeared from its inner side. In APLACENTALIA, and in some other mammals, the configuration of the bones and the mode of connexion with the wrist permit some pronatory and supinatory movements; but they are generally very limited. The gigantic fossil sloths however—the MEGATHERIUM and MYLODON—appear to have enjoyed considerable range of pronation and supination, if we may judge from the shape of the articular surfaces of the radius and the mode in which the cuneiform bone was connected with the ulna. That this power has no especial relation to the presence of the *pollex* is shewn by the fact that in one of these animals—the Mylodon—the pollex, though parallel with the other digits, has its proper complement of bones, whereas in the other—the Megatherium—it is reduced to a rudimentary trapezium.

PROXIMAL SEGMENT OF THE FORE LIMB.

Humerus; indications of tendency to division in lower end.

The bone of the upper, or proximal, segment of the fore limb is single and pretty uniform in its characters in all vertebrates, and presents an articular facet for the scapula above and for the bones of the middle segment below. A tendency to longitudinal fission, analogous to that in the lower end of the

[1] The olecranon is absent or only rudimentary in most CETACEANS, though not in all (see fig. 26). In the BAT it is a detached ossicle, and the ulna terminates at the lower third of the forearm.

double metacarpal of the ruminant, may be recognised at the widened lower end of the humerus, inasmuch as an outer and an inner condyle are appropriated respectively to the radius and to the ulna; moreover, an interval between the two condyles is perceptible in some animals (Quadrumana and Carnivora, and occasionally in Man).

Relative length of humerus.

The length of the humerus in relation to the rest of the skeleton and to the other segments of the limb is greatest in Man. It slightly exceeds that of the radius and ulna in Sloths and in many carnivorous animals, in some Pachyderms, and, more distinctly, in Reptiles, for the purpose of extending the limbs wide of the trunk without raising the latter much above the ground; but it is inferior in Solidungula, Ruminantia, Cheiroptera and most Birds. In the Apteryx and other birds, in which the middle and distal segments of the limb are disproportionately short, the humerus, as before mentioned, is long in comparison with the bones of those segments, though short in comparison with the rest of the skeleton.

Thus we see in the mode of construction of the fore limbs of the several classes of vertebrate animals an admirable illustration of the mode in which the combination of the two great principles—unity of plan and adaptation to especial requirements—are carried out in the works of nature; how, on the one hand, the former is never lost sight of, yet on the other it is not pushed to such a degree as to be inconvenient to the animal, but is sacrificed, to a greater or less extent, to fit the limb for the fulfilment of its various purposes.

THE DISTAL SEGMENT OF THE HIND LIMB.

The hind limb is formed upon the same plan as the fore limb; each of its segments consists of the same number of bones, with a few exceptions in the distal portion; and the bones of the one limb correspond with, or are homologous with, those of the other. The chief difference results from the fact that the hind limb plays a more efficient part in propelling the trunk, and is, consequently, longer, stronger, and more compact. The difference becomes more apparent in proportion as the work of propulsion is delegated to the hinder limbs, and is, therefore, most marked in man.

Features of pollex pedis in man as characteristic as those of pollex manus.

In the human foot the *pollex*, instead of being, like the *thumb*, shorter, and more moveable, than the other digits, is as long, or longer, and larger than any of them; it is also articulated with the tarsus in such a manner as to permit very little movement, but so as to fit it to perform an important part in bearing the weight of the body. These features of the great toe characterize the human foot in as distinct a manner as those of the thumb do the hand; for in no other animal does the *pollex* of the *hinder foot* attain to the same relative dimensions, or form so important an element in the foot, as it does in man.

Tripartite division of distal segment.

The tripartite division of the foot corresponds, in a general manner, with that of the hand, though it is less clearly defined. There is a greater tendency to fusion of bones for the purpose of giving strength; and there are more irregularities, or varieties, in the disposition of the parts here than in the fore limb. In man and

most mammals the *astragalus*[1], or middle bone of the first row (see Diagram, Pl. I. fig. 4, 6′) is raised above the *scaphoid* and the *os calcis*, just as in the fore limbs of some reptiles (Pl. II. figs. 24 and 25; Pl. III. figs. 7 and 9) its correspondent—the *lunar*—is raised above the *scaphoid* and the *cuneiform*. The *cuboid*, like the *unciform*, carries the outer two toes, and is itself carried upon the *os calcis;* and these, together, form the outer division of the foot. The *scaphoid* covers the whole of the anterior surface of the *astragalus*, being prolonged between it and the *external cuneiform*—the representative of the os magnum —so that it carries the digit (III.) together with digits I. and II., reminding us of the disposition of parts in the fore foot of some tortoises (Pl. II. fig. 25). The representative of the *pisiform* bone of the fore limb forms the hinder part of the os calcis, being conjoined with that bone for the purpose of giving greater power to the attached muscles[2].

Digits disappear in same order as in fore limb.

The disappearance of the toes in CARNIVORA, RODENTIA, EDENTATA, and PACHYDERMATA, and their reappearance in REPTILES, take place much in the same order as in the case of the fore limb[3]. In some animals they are more persistent in the hind limb than in the fore; and in others the reverse is the case[4]. The same rules are also observed with regard to the number of digits, and the number of bones in each digit. The toes do not exceed five; the bones of the pollex are restricted to three, including the metacarpal, and those of each of the other toes in terrestrial mammals to four, while in Birds and Reptiles the bones are increased to five and six in the outer two toes. In many Birds the increase is progressive from two phalanges on the rudimentary inner digit, to five in the outer one.

Relative size of digits varies.

In the human foot, as already remarked, the pollex far exceeds the other toes in size and strength; and there is a gradual diminution from it to the fifth toe, the weight being borne chiefly by the inner side of the foot. In all other animals the pollex is the smallest of the series, and there is a gradual increase as we travel outwards to the third, fourth, or fifth. In SOLIDUNGULA the third is developed far beyond the others,

[1] M. Gervais, *Annales des Sciences Naturelles*, 1853, xx. 42, conceives that the *astragalus* is a compound bone corresponding with the *scaphoid* and *lunar* of the carpus, and thus resembling the *scapho-lunar* bone of many mammals; and he thinks that the *scaphoid* of the tarsus corresponds with the *os intermediare* which is found in the carpus of some quadrumanous animals and rodents. It must be observed, however, that the usual evidences of the compound nature of a bone—viz. that its component parts are found separate in the fœtus or are permanently separate in some animals—do not appear to be forthcoming in this instance. Moreover the comparison of the *astragalus* with the *semilunar* bone in some of the Iguanidæ and in the Plesiosaurus and the Ichthyosaurus clearly proves their homologous nature, and prepares us for that complete elevation of the astragalus above the other two bones of its row which renders it the sole medium of articulation with the tibia and fibula.

[2] Vicq-D'Azyr, *Mém. de l'Académie Royal des Sciences*, 1774, p. 262, pointed out the correspondence of the bones of the tarsus with those of the carpus—the astragalus with the semilunar—the os calcis with the united pisiform and cuneiform, &c.

[3] It is, however, worthy of remark, that in many reptiles the fifth toe is small or absent although the pollex is of considerable size. Thus in some land TORTOISES it consists of only two small bones resting upon the outer part of the cuboid; while this latter is separate from the inner part, and is prolonged into the place of the digit, just as the trapezium in the fore foot of the ELEPHANT, and the internal cuneiform in the hind foot of the CAPE BEAR, are prolonged to supply the deficiency of the pollex. In some other TORTOISES and in the ALLIGATOR there is only one bone representing the fifth toe; and in some there is no trace of a fifth toe.

[4] "In the hind foot of the ORANG, commonly, and in that of the WOMBAT, the short metatarsal of the inner digit supports but one phalanx. In the DOG the inner digit is usually wanting in the hind foot, and is always diminutive in the fore foot. The first digit of the hand is reduced to a short metacarpal in the spider-monkey." Owen, *On the Nature of Limbs*, p. 35. In the HYÆNA (Plate II. fig. 29) two small bones which look like phalanges are connected directly with the scaphoid without there being any intermediate metatarsal or cuneiform.

and in Ruminantia the third and fourth. In Quadrumana, most Carnivora, Rodentia, and Pachydermata, the third and fourth are of nearly equal size and preponderate over the others. In Kangaroos, Birds and Lizards, the third or the fourth is the largest. This is particularly marked in the Great Kangaroo (Pl. I. fig. 5), the second and third toes being mere splinter-like appendages along the inner side of the enormously developed fourth toe. In the Bear the fifth toe is rather longer and larger than any of the others.

Tarsal bones.

The number and arrangement of the tarsal bones in most mammals are much the same as in the human foot. In Ruminants (Pl. II. fig. 10, 5′ and 12′) the *scaphoid* and *cuboid* are united; and the *cuneiform* bones (11′) are reduced to one or two. In Solidungula (fig. 11) that which corresponds to the external, or small, cuneiform in man is of great size, to articulate with the largely-developed third metacarpal; it is also united with the scaphoid, and the middle cuneiform and the cuboid are small. In some Edentata and Rodentia there are more than seven bones in the tarsus; though the additional bones, like those in the carpus of the Armadillo, seem rather to have the character of sesamoid bones. Thus in the Beaver there is a bone beneath the head of the astragalus, between the anterior extremity of the os calcis and the internal cuneiform, in the position occupied by the tendon of the *tibialis posticus*. In Birds (fig. 35) the tarsus and metatarsus are represented by one long cylindrical bone, exemplifying in the highest degree that principle of the association of lateral fusion with elongation which we find to be more or less carried out in the limbs of all animals. This long tarso-metatarsal bone exhibits near the upper end a tendency to division into two, and there is often an interval between the two. Below it is tripartite, presenting three distinct articular facets, one for each of the outer three toes; and the second and first toes, when present, are carried upon the inner side of the shaft of the bone and diverge from the others in a more or less backward direction[1]. In the Penguin the tarsus is shorter and broader and is composed of three cylindrical bones fused at their sides; or they may be ankylosed only at their ends with interspaces between their shafts. In Reptiles (Pl. III. fig. 4) the bones of the proximal row—the *scaphoid*, *astragalus*, and *os calcis*—are united into one large bone, or into two; of these two one represents the *scaphoid* and *astragalus*, and the other, which is of smaller size, is the *os calcis;* so that a representative of each of the three constituents of the proximal tarsal row enters, as in the case of the carpus, into the joint with the bones of the middle segment of the limb. These bones are connected by means of the *cuneiform* and *cuboid* bones, which vary in number from one to five, with the metatarsals. In the Frog the proximal row of the tarsus is represented by two long cylindrical parallel bones; and the distal row is abortive or nearly so.

MIDDLE SEGMENT OF THE HIND LIMB.

In the middle segment of the hinder limb the principle of amalgamation for the purpose of solidity and strength is observed in the fact that in all Mammals and Birds one bone—the

[1] It is worthy of remark that the epiphysis of this tarso-metatarsal bone, unlike the epiphyses of the metatarsal bones in other animals, is formed at the upper end. It may be that, as in the case of the mammalian tibia, which this bone resembles in shape and function, an epiphysis is formed also at the lower end; if so it is of shorter duration than the one developed at the upper part.

tibia—forms the medium of connexion between the femur and the tarsus. The other bone —the *fibula*—bears very little weight; its chief office is to extend the surface for the attachment of muscles. In no mammal does it reach the femur; and in all placental mammals it is articulated only with one bone of the tarsus, viz. the side of the *astragalus*. In some aplacentals it is connected with the upper edge of the *os calcis*, as well as with the astragalus. In BIRDS it is articulated with the outer condyle of the *femur*, as well as with the *tibia;* but quickly tapers, and disappears at the middle of the leg. In REPTILES it forms a more important constituent of the leg, being of comparatively large size; and, in addition to being united with the *tibia*, it presents broad surfaces for articulation both with the *femur* and with the *os calcis* (Pl. III. fig. 4)[1]. The greater similarity between the mode of construction of the fore and the hind limbs in these animals, as compared with the higher vertebrates, which is thus evinced in the middle segments, is also carried out, as we have just seen, in the disposition of the tarsal and the carpal bones; it has relation to the greater similarity of function of the limbs of Reptiles as compared with the limbs of the higher animals.

The *fibula* is on the whole a less important bone in its segment than is the *ulna*. We, accordingly, find that in the mammalian series it disappears more suddenly and more completely than is the case with its homologue in the fore limb. Thus in the ELEPHANT (Pl. II. fig. 7), the HIPPOPOTAMUS (fig. 8), and the RHINOCEROS (fig. 9), though present in its whole length, it is relatively very much smaller than the *ulna*, and in RUMINANTS (fig. 10) and SOLIDUNGULES (fig. 11) it is quite absent; whereas in the latter the upper articular portion of the *ulna* is of large size, and in the Pachyderms the *ulna* is continued down to the carpus. Moreover, in the fore limb, the great extensor tendon is attached to the *ulna;* and its bone—"the elbow-pan"—is commonly conjoined with the olecranon, though in some birds it is separate from it; whereas, in the hinder limb, the extensor tendon is connected with the *tibia;* and its bone—"the knee-pan"—usually remains separate. In some of the APLACENTALS, it is true, the *fibula* is prolonged above the knee-joint; but this is on the outer side not on the fore part of the condyles of the femur. Moreover it is not commonly articulated with the condyles, being separated from them by an interval; and its unusual development in these animals is for the purpose of giving power, not to the extensor muscles of the leg, but to the muscles that effect the movements of the foot and that rotation of the foot and the *tibia* which, in some of these animals, takes place upon the *fibula*.

PROXIMAL SEGMENT OF THE HIND LIMB.

The single bone of the proximal segment resembles the humerus in its general features; and its great proportionate size, in relation to the other segments of the limb, and to the rest of the skeleton, constitutes, even more markedly than in the case of the humerus, one of the characteristic features of the human frame[2].

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[1] In the FROG the *tibia* and *fibula*, like their homologues in the fore limb, are united into one bone. In the BAT a slender *fibula* ascends from the outer malleolus and terminates about the middle of the leg.

[2] See "the Proportions of the Human Figure," in my *Treatise on the Skeleton*, p. 60. Still in some CARNIVORA, in SLOTHS, PACHYDERMS, and REPTILES it is as long, or longer, than the tibia.

ON THE COMPARISON OF THE FORE AND THE HIND LIMBS.

Difficulty in instituting exact comparison of limbs.

A very superficial observation is sufficient to shew the similarity between the fore and the hind limbs, and to indicate generally the homology of their several parts. But a difficulty arises in instituting an exact comparison between the two; inasmuch as the upper end of the *ulna* is situated on the *inner* side of the forearm, and is connected with the inner condyle of the humerus, and the *olecranon* is on the *posterior* aspect of the elbow; whereas the *fibula* lies in its whole length on the *outer* side of the limb, and the *patella* is in *front* of the knee. The position of these bones led Vicq-D'Azyr and Cuvier to regard the fore limb of one side as corresponding with the hinder limb of the opposite side; it induced Cruveilhier to consider that the upper end of the tibia is represented by the upper half of the ulna, and the lower half of the tibia by the lower half of the radius, the fibula being represented by the upper half of the radius and the lower half of the ulna; and it has led Professor Owen to consider the prolongation of the fibula in the wombat to be the homotype of the olecranon, and the sesamoid bone developed in the tendon of the *biceps brachii* of certain bats to be the homotype of the patella.

It does not appear to me that these, or any other of the many views which have been offered, are satisfactory; and I think that a different explanation may be given, and the true homology of the parts may be determined by attention to two or three points.

Antagonistic mode of action and construction of the proximal segments.

The fore limb is situated near the anterior part of the trunk, and is designed to drag the body *after* it. To do this, it is, first, thrown forwards and placed upon the ground in a state of extension; and, then, by shortening itself, it draws the body onward. The hinder limb, on the contrary, situated near the posterior part of the trunk, is designed to propel the body *before* it. To do this, it is, first, bent and placed upon the ground in a state of flexion; and, then, by elongating itself, it drives the body forward. The position and mode of action of the two limbs being thus antagonistic, the flexures of their several parts, of those at least nearest to the trunk, are also antagonistic. The *pelvis* and the *femur* slant forwards from the hip: whereas the *scapula* and the *humerus* slant backwards from the shoulder. The knee is bent forwards, and the elbow is bent backwards. The opposed surfaces of the two limbs correspond; and the surfaces which are directed away from one another also correspond. Thus, the posterior (antero-inferior in man) edge of the *scapula* corresponds with the anterior edge of the *ilium;* and the smooth convex posterior surface of the *humerus* corresponds with the smooth convex anterior surface of the *femur.* The humerus is bent *for*wards at the upper part, and *back*wards below; which is just the converse of the flexures of the femur. The neck and head of the former bone are

directed *back*wards and inwards towards the glenoid cavity, whereas the corresponding parts of the femur are directed *for*wards and inwards; and the articular surface is prolonged upon the *ant*erior aspect of the condyles of the humerus, and upon the *post*erior aspect of the condyles of the femur[1].

The disposition of the muscles, vessels, and nerves is also in accordance with this antagonistic arrangement of the upper parts of the limbs.

Antagonistic disposition of the Muscles,

Thus, the *triceps extensor cubiti* passing from the *hinder* edge of the scapula, near to the glenoid cavity, along the *back* of the arm, to the olecranon, evidently corresponds with the *quadriceps extensor cruris*, which passes from the *anterior* edge of the ilium, near to the acetabulum, along the *front* of the thigh, to the patella and the tibia. The flexors of the elbow pass in *front* of the joint, partly from the *ant*erior edge of the scapula, and partly from the *ant*erior surface of the humerus, to the radius and ulna; and the flexors of the knee pass, *behind* the joint, partly from the *post*erior edge of the pelvis, and partly from the *post*erior surface of the femur, to the tibia and fibula. The *subscapularis* and *latissimus dorsi* pass from the inner surface of the scapula, and from the posterior aspect of the spinal column, downwards and *for*wards, to the lesser tubercle of the humerus; and the *iliacus internus* and *psoas magnus* pass from the inner surface of the ilium and from the anterior aspect of the spinal column, downwards and *back*wards, to the lesser trochanter of the femur.

of the Arteries,

The Brachial artery, emerging from the chest, passing *behind* the coracoid process and separated from the shoulder-joint by the subscapularis muscle, runs downwards and *for*wards to the *front* of the arm and elbow, where it divides into its radial and ulnar branches; whereas the Femoral artery, emerging from the abdomen in *front* of the pubes and separated from the hip-joint by the psoas muscle, runs downwards and *back*wards to the *hinder* aspect of the thigh and knee, where it divides into its anterior and posterior tibial branches.

of the Nerves.

With regard to the nerves, also, the main trunks descend along the *front* of the arm and elbow, and along the *back* of the thigh and knee. The median, ulnar, and external or musculo-cutaneous nerves, supplying the flexor muscles of the forearm and hand as well as the skin of the palmar surface of the hand, correspond with the portion of the sciatic which supplies the flexors of the leg, and with the posterior tibial branch which supplies the flexors of the foot as well as the skin of the plantar surface of the foot. The radial nerve, supplying the extensors of the forearm and hand as well as the skin of the anterior surface of the latter, corresponds with the branches of the anterior crural nerve, which supplies the extensors of the leg, and with the peroneal branch of the sciatic which supplies the extensors of the foot and the skin of the anterior surface of the foot[2]. It would be

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[1] The inverted position of the limbs with regard to one another attracted the attention of Dugès. He remarks, *Traité de Physiologie comparée*, II. 204, that the *elbow* is opposed to the *knee*, the *olecranon* to the *patella*; that the *ischium* seems to represent the *clavicle*, and the *pubes* answers to the *coracoid*.

[2] In the Frog the nerves of the fore limb descend in two trunks corresponding with the median and the radial; of these the distribution of the former answers to that of the median, ulnar, and musculo-cutaneous in man. The same is the case in the Bird. In the Rabbit, and probably in many other mammals, the branches answering to those of the musculo-cutaneous are derived from the median in the middle of the arm.—Cuvier, *Leçons d'Anat. Comp.*

interesting to trace these nerves to their respective sources in the spinal cord, and to ascertain whether the antagonistic principle is observed in the order of their connexion with the neural axis; that is to say, whether the nerves supplying the extensors of the elbow and knee (the muscles lying on opposed or approximated surfaces of the arm and thigh) are connected with the opposed or approximated regions of the cord. To a certain extent we can perceive that this is the case. Thus the radial nerve, which supplies the triceps extensor cubiti as well as the muscles and integuments of the dorsal aspect of the forearm and hand, arises chiefly from the hinder division of the nerves which form the brachial plexus; and the anterior crural nerve, which supplies the quadriceps extensor cruris and the integuments of the anterior aspect of the knee and leg, arises from the spinal cord in front of the nerves which pass to other parts of the limb. The intricate interlacement, however, of the nerves on their way from the cord to the limbs, and especially to the fore limbs, renders it difficult to pursue such an investigation with satisfactory results.

This very difficulty, together with the circumstance that it is encountered most in the fore limb, in consequence of the nerves being so blended with one another in the brachial plexus, is a feature of additional interest, and accords well with the fact that the antagonism between the limbs affects only the parts nearest to the trunk, as well as with the mode—to be presently discussed—in which the antagonism of the proximal parts is established during development, while the corresponding surfaces of the distal segments continue to maintain a direct relation to one another.

Correspondence of distal segments.

That the distal segments of the fore and hind limbs do thus correspond, agrees with the mode in which their function is performed, just as does the antagonistic arrangement of the parts nearer to the trunk. The fore and hind feet are both pressed upon the ground in the same manner, and are withdrawn from it in the same direction. Their movements accordingly correspond, and the homologous structures in them are turned the same way. That is to say, their palmar and plantar surfaces are directed backwards and downwards, and the pollex, when present, forms the inner digit of either member; moreover, the disposition of the vessels and nerves is conformable with this direction. It is for the purpose of accomplishing this harmony in the disposition of the distal segments of the two limbs in all the upper classes of animals, that the radius crosses in front of the ulna and is rotated upon its axis; and this direction and the rotation of the radius give the prone position to the terminal parts of the fore limb.

A brief account of some of the changes which occur during the development of the limbs will enable us better to understand these points.

Changes in direction of segments of limbs during development.

At first the limbs are projected from the sides of the trunk, as mere flattened processes, with their surfaces directed outwards and inwards; and they have rounded ends from which, at a subsequent period, the digits grow out. The processes become elongated and pediculated; they run outwards in a parallel direction; and no difference can be distinguished between the anterior and the posterior limbs. Soon an angle or flexure is observed in each pedicle; that in the anterior limb forming the elbow, and that in the posterior the knee. The two joints are precisely alike; and they are both bent upwards. The arm and the thigh are short, and are directed out-

wards; and the remainder of each limb is directed downwards and inwards. Next, a partial rotation of the limbs takes place; but in opposite directions, the elbow being turned backwards and the knee forwards, so that the two approach one another, and almost come into contact. This change is attended with flexures at the shoulder and hip, which are also in opposite directions; and the scapula, which at first was vertical—in the same line with the humerus—undergoes a rotation upon a transverse axis, and thereby assumes a more or less oblique direction. The position of the hand and foot is, at present, dependent upon that of the forearm and leg; so that, in consequence of the twist which has taken place, the tips of the fingers are directed forwards, and those of the toes backwards; the palm is turned inwards and the sole upwards. Gradually, however, the direction of the terminal segments becomes altered. By a partial rotation of the hand, or forefoot, inwards, that is, in an opposite direction to the upper part of the limb, and by a slight flexure of the wrist in an opposite direction to that of the elbow, the palm becomes turned backwards, and the ends of the fingers are directed downwards. The terminal segment of the hinder limb does not undergo any corresponding rotation to that of the fore limb; but by a flexure at the ankle, in an opposite direction to that at the knee, and in an opposite direction also to that at the wrist, the sole becomes turned downwards, and the ends of the toes are directed forwards[1].

There are thus four stages in the development of the limbs. *First,* that in which the limbs are straight short processes running out in a parallel manner from the trunk. *Secondly,* that in which the flexures of the elbow and knee take place, the similarity between the limbs being still preserved. *Thirdly,* the rotation of the limbs in opposite directions causes an antagonism in their upper parts and approximates the elbows and knees. *Fourthly,* the flexures of the wrist and ankle and the pronation of the forearm and hand preserve the correspondence between the distal segments.

Successive positions represented by permanent condition in lower animals; in Fishes,

It is interesting to observe the extent to which each of these successive positions of the limbs is retained as the permanent condition in some of the lower animals. In the fins of Fishes the primal form remains; there are no flexures; the terminal segment preserves the same direction with the pedicle; and the latter is very short and does not undergo rotation.

in Reptiles,

In Reptiles the limbs are short, and run out sideways, allowing the belly of the animal to rest upon the ground; the flexures of the elbow and knee take place; but there is, as a general rule, little or no rotation of the segments, or inclination of the fore and hind limbs towards one another; and the scapula and pelvis are nearly in the same lines with the humerus and femur. Hence the direction and conformation of the fore and hind limbs is very nearly alike. The thighs and the arms run out laterally from the trunk in almost parallel lines; the elbows and the knees are bent upwards; the forearms and the legs pass downwards; the two bones of the middle segment take a nearly parallel course in each and contribute about equally to the formation of the joints with the proximal and with the distal segments; the fore and the hind feet are directed more or less outwards, in

[1] See Baer, *Entwickelungsgeschichte der Thiere*, § 84, 108, and Goodsir, *Edinburgh New Philosophical Journal*, 1857, p. 179.

consequence of the flexures at the wrist and the ankle corresponding nearly with one another; and the pollex is, in each limb, on the anterior aspect of the foot. Both the olecranon and the patella are absent, or nearly so[1].

In some REPTILES, however, a certain amount of inclination of the elbows and knees towards one another is observed; and this is accompanied by a proportionate rotation of the arm and a pronation of the hand and forearm, thus presenting an approximation to the position of the limbs in the higher animals. In the FROG, indeed, pronation takes place to such an extent as to turn the ends of the fore digits inwards.

in Birds,

In BIRDS the folding of the elbows and knees towards one another is complete; and the distal segments of the wing are in a position midway between pronation and supination. The olecranon and patella are still commonly absent. The obliquity of the scapula and of the ilium is usually very marked.

in Mammals.

In terrestrial MAMMALS the degree of flexion is not commonly so great as in REPTILES, the limbs being straighter, as well as longer, for the purpose of raising the trunk to a greater distance from the ground and of giving greater speed. The rotation of the segments, however, and the consequent inclination of the elbows and knees towards one another so as to bring the limbs more directly under the trunk, are more complete; but they take place in different degrees in different members of the class; and in most mammals, the humerus and the femur, though directed more vertically than in other animals, retain more or less obliquity, the humerus slanting outwards and *back*wards, and the femur slanting outwards and *for*wards.

The relation of the Patella to the inner and outer condyle of the femur varies with the degree of rotation of the limb.

It is worthy of remark that in proportion as the rotation of the limb is less or more complete, and the outward slant of the thigh is greater or less, so the inner condyle of the femur is more or less prominent anteriorly, and contributes, in a greater or less degree, to the formation of the trochlea for the patella. Thus, in the HORSE, the OX, and indeed in MAMMALS below QUADRUMANA as a general rule, the thigh slants outwards, the inner condyle of the femur is more prominent than the outer, and the patella rests chiefly upon it. Hence the inner articular facet of the patella is the larger.

In the MONKEY the thigh descends nearly vertically from the pelvis, the two condyles of the femur are equally prominent and share the patella equally between them; and there is little or no difference between the two articular facets of the patella. In MAN the thigh slants a little inwards; the rotation of the segment is carried to a greater degree than in other animals; the outer condyle of the femur is more prominent anteriorly than the inner; and the patella rests chiefly upon it, and, accordingly, presents the outer articular facet of greater size than the inner. By comparing, therefore, the relative dimensions of the articular facets of the patella, we may form a tolerably correct estimate of the degree of rotation of the thigh and of its angle of inclination from the trunk.

In nearly all terrestrial mammals the patella and the olecranon are present. Pronation is the common, in many it is the constant, position of the terminal parts of the fore limb. In

[1] In the Scincus, represented Pl. III. fig. 6, there is a small patella.

some mammals partial supination can be effected; but in man only are complete supination and pronation possible.

The unrolling of the limbs by muscular action.

It may be observed that the oblique direction in which the muscles, vessels, and nerves run, from the trunk and the scapular and pelvic arches, and along the proximal segments of the respective limbs, in man and most mammals, is precisely in accordance with the view that those segments have undergone a partial rotation, in opposite directions, in the two limbs. This disposition of the muscles gives us the power to reverse the rotation, that is, to unroll each limb, to a considerable extent. Thus we are able to rotate the humerus so as to make its outer condyle present *for*wards, or in its original direction, more freely than we can turn it backwards; and in the hinder limb the reverse is the case, inasmuch as we can turn the outer condyle of the femur *back*wards more freely than forwards. Moreover these rotatory movements of the thigh and arm are most free in man, which accords with the fact that the twisting of the limbs during development takes place in him to a greater extent than in any other animal. When the limbs are thus unrolled into their primitive conditions—when the elbows and knees are turned away from one another —then the direction of the vessels and nerves, in each limb, is seen to be more nearly parallel with the direction of the bone.

Changes in limbs in ascending series of animals.

Thus, beginning with the FISH and ascending to MAN, we trace, in the limbs, a gradually increasing divergence from the simple straight primitive form which is common to the early fœtal state in all the classes; we find a gradual increase in the solidity and strength of the hind limbs, till they attain that perfection which enables them, in man, to bear all the weight and do the whole work of progression; and we observe, also, an increase in the variety and facility of the movements of the fore limbs, whereby they are, more and more, adapted to their manifold purposes, in subservience to the will, as they become released from the subordinate office of sustaining the trunk.

It is necessary to make a few additional remarks respecting the *Patella*.

Patella not a mere sesamoid.

Forasmuch as the patella is closely connected with and subservient to a tendon, moving with it and connected with the rest of the skeleton only through its medium, there are some grounds for the opinion of those anatomists who regard this bone merely as a sesamoid bone, and as forming, therefore, no part of the regular skeleton[1]. Nevertheless I cannot but think that there are equally strong grounds for an opposite view; and that the constancy of the patella in the Mammalian class (it is absent only in the KANGAROO, some BATS, and some CETACEANS), the regular thick layer of cartilage upon its articular surface, and its development from true fœtal cartilage, instead of from fibro-cartilage like the sesamoid bones, are reasons for connecting it with the true skeleton; and I incline

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[1] Bertin, Bichat, and others. Flourens also, *Mém. d'Anat. et de Phys. Comparées*, I. 97, regards the patella as a mere sesamoid bone, and not, therefore, to be compared with the olecranon, which is a veritable epiphysis.

to the opinion of Vicq-D'Azyr, Cuvier, and those anatomists who see in the *patella* the correspondent or homologue of the upper part, or epiphysis, of the *olecranon.*

Reasons for regarding the patella as the homologue of the olecranon.

Such an opinion agrees entirely with the mode in which the comparison of the limbs has been just traced out, and with the changes of position which have been shown to take place during the development of the limbs. The patella and the olecranon are each situated upon the convexity of that flexure which takes place between the proximal and middle segments of either limb. At first, they are both upon the dorsal aspect of the limbs; subsequently, they become turned towards one another, or antagonistic; just like all the parts, which are at first dorsal, in the proximal divisions of the two limbs. The relations of the patella with the knee-joint and with the condyles of the femur are precisely similar to those of the olecranon with the elbow and with the condyles of the humerus. The office of the one corresponds with that of the other; and the muscle with which the patella is connected, and to which it is subservient—the *quadriceps extensor cruris*—is clearly the homologue of the *triceps extensor cubiti*, to which the olecranon is subservient. Moreover, the two exist and disappear together in the several vertebrate classes with very few exceptions[1].

The relations of the olecranon-epiphysis and the patella to one another are well illustrated in Birds. A strong broad process, usually, runs up from the tuber tibiæ, resembling and corresponding in function with the olecranon, and a small patella, or "knee-pan," may be found behind this process, distinct from it or (as in the Albatross and Colymbus) ankylosed with it. In the Penguin there are two patellæ set close upon the tuber tibiæ, yet distinct from it and from one another. The olecranon in Birds is shorter than in Mammals; and there is often situated, just above it, in the extensor tendon, an ossicle, which, from its similarity in position and function to the knee-pan, has been called the *patella brachialis*, or "elbow-pan." In the Penguin there are two such ossicles in the arm, resembling and almost exactly harmonizing with the two at the knee[2].

Differences of position and mode of connection not sufficient reasons against homology of olecranon and patella.

True, the olecranon-epiphysis is usually connected with the ulna[3] and forms part of it, or becomes ankylosed to it, whereas the patella is united only by ligament with the tibia; and further, the tibia is not the homologue of the ulna. But there is nothing very remarkable or unusual either in a slight variation in the position of homologous bones, or in their remaining free at one part of the skeleton and being ankylosed at another. The most familiar and generally admitted examples of shifting of position are supplied by the ribs, which, in some parts, are ankylosed with the superior transverse processes of the vertebræ, in others, are merely jointed with the extremities of those processes, and, in others again, are quite free from them, resting

[1] In the Scincus there is, sometimes, a diminutive osseous patella, but no olecranon; and in the Kangaroo and some Bats there is an olecranon, but no patella.

[2] In Salamanders there is a small patella in the tendon of the extensor muscle of the elbow corresponding with that in the extensor muscle of the leg.—Cuvier, *Leçons d'Anat. Comp.* I. 412.

[3] In the Camel the ulna has entirely disappeared with the exception of the olecranon portion; and the latter appears as a mere process growing up from the back of the radius. Its relation with the radius here exactly corresponds with that of the patella to the tibia; except that it is united to the radius by bone, whereas the connection between the patella and the tibia is ligamentous.

only upon the inferior transverse processes, and, it may be, even upon the vertebræ to which they do not properly belong. It is needless to multiply instances of the like kind by reference to the odontoid process of the axis, many of the components of the cranium and other parts of the skeleton, especially as the opinions of anatomists are divided respecting many of these; and few persons will be disposed to require exact correspondence of position as a condition necessary to homology. Still less will it be regarded essential that the homologous bones should be shown to retain the same kind of connection with the adjacent parts in different regions of the skeleton. Of a departure from this we have already seen an instance in the case of the *pisiform* bone, which usually remains free, whereas its correspondent in the hind limb is ankylosed to the os calcis[1].

The manner in which the head of the fibula in the Ornithorhynchus and in some other monotrematous and marsupial animals, "extends above the knee-joint and is expanded like the olecranon in the mole's ulna," induces Professor Owen[2] to regard these two parts as homologous; and he considers the superadded ossicle in the Wombat's fibula as the parallel to the superincumbent ossicle in the Mole's olecranon. It must, however, be borne in mind that the expansion of the fibula in the animals just mentioned has relation, not, as in the case of the olecranon, to the extensor muscles of the middle segment, but rather to the muscles which act upon the foot; and I cannot but think that this consideration, and an examination of the other marsupial animals clearly prove that the ossicle on the top of the fibula of the Wombat and the Dasyure (Pl. II. fig. 14, *s*) corresponds with the ossicle situate just beneath the outer condyle of the femur in the Kangaroo-rat (Pl. I. fig. 6, *s*) and the Bandicoot Opossum (Pl. I. fig. 7, *s*); and there can be little doubt that this corresponds, not with the olecranon ossicle of the Mole, but with the ossicle which is occasionally found in the outer head of the gastrocnemius in man and in other mammals. Whatever view, therefore, may be taken of the homologous relations between the expanded upper end of the fibula in these animals and that prolongation of the upper end of the ulna which forms the chief part of the olecranon, the muscular relations of parts clearly prove to my mind that the superincumbent ossicle occasionally met with near the head of the fibula is not the homologue of the ossicle or epiphysis which is developed in connection with the olecranon and which ministers to the extensor of the forearm[3]. For the same reason I cannot agree with the distinguished authority just referred to that the sesamoid in the tendon of the biceps in the front of the Bat's elbow is the true homotype of the patella in the leg[4]. Unless we are entirely to disregard the guidance of muscular relations in determining homology we must be content to admit that the ossicle upon the olecranon is the homotype of the patella; and

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[1] An analogy between the *patella* and the *pisiform* bone may be drawn a little further. Each is situated upon the convex side of its respective joint, and ministers to the tendon which extends the joint, yet differs from an ordinary sesamoid in structure, and in being developed from cartilage; and the homologue of each, in the opposite limb, is conjoined with the adjacent bone; and each may be regarded as intermediate between a sesamoid bone and a process of the skeleton. The patella is connected with the tibia and its correspondent in the arm is connected with the ulna, because those bones form the chief constituents of their respective joints and of the adjacent parts of the leg and forearm.

[2] *On the Nature of the Limbs*, p. 23.

[3] M. Martins (see footnote on next page) regards the ossicle at the top of the Wombat's fibula as a patella, and adduces it as an evidence of the correspondence of the patella with the olecranon. It is to be observed, however, that in some Marsupials the patella is fully developed in the usual position in front of the knee; see also ornithorhynchus, Pl. II. fig. 20, 4'.

[4] Owen, *loc. cit.* page 19.

a parallel to the ossicle in the tendon of the biceps must be sought in one of the flexor tendons of the leg.

Arguments against the theory of "torsion of the humerus."

M. Charles Martins, Professor of Natural History at Montpellier[1], carries out the comparison between the limbs by regarding the humerus as being twisted, on its axis, in the shaft, to the extent of 180°; and observes, that if it be untwisted, so as to bring the internal condyle, first forwards and then to the outer side, the olecranon will be thrown to the front, and all difficulty in comparing the upper with the lower limb of the same side will cease. To this it must be objected, that, although the relations of the articular surfaces of the humerus to one another, and the direction of the lines upon its shaft are oblique, and so might be thought to offer some countenance to such a view, yet that the same kind of obliquity may be observed in the case of all, or nearly all, the other long bones; and the lines upon the humerus and other long bones do not appear with any degree of distinctness till the general form of the bones has been acquired and the position of the articular surfaces fixed. Secondly, No such torsion as that contended for has been observed to take place at any period of development. M. Martins is aware of this; and, therefore, describes it as a *virtual*, rather than as an *actual*, torsion. Thirdly, This supposed *virtual* torsion is in an opposite direction to the *real* torsion of the limb, which takes place during development, and which has been referred to in the preceding pages. It does not, therefore, accord with the disposition of the various soft parts. Fourthly, It is improbable that an important principle would have been carried out so completely in the humerus, without there being something of a similar nature observable in the case of the other long bones, more especially in the femur, which M. Martins does not admit to be the case.

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[1] *Nouvelle Comparison des Membres Pelviens et Thoraciques*, Montpellier, 1857, reprinted from the *Mémoires de l'Académie des Sciences et Lettres de Montpellier*, Tom. III.; an able memoir, in which the author has gone very fully into the subject and has given a careful résumé of the opinions of preceding writers upon it.

THE SCAPULAR AND PELVIC ARCHES

Scapular and Pelvic arches closely related to the limbs though ministering to the visceral system.

are present in some animals in which there are no traces of limbs[1]; and in the human subject they are rarely wanting, even in cases where all the other components of the limbs fail to be developed. Moreover they have, the pelvic arch in particular, a more or less close relation to the visceral system, and so present a claim to be regarded as parts of the trunk. Nevertheless, their chief functions obviously have relation to the limbs: they are modified in shape in accordance with the requirements of the limbs; and, as a general rule, they are not developed in those animals which have no limbs. It is clear, therefore, that they must be taken into account in any theories that we may form respecting the nature, or construction, or mode of comparison, of the limbs; and we are prepared to find a general uniformity in the plan of their formation throughout the several classes of the vertebrate order.

A scapular, and also a pelvic arch, consists usually, on each side, of three bones. These come into contact, or are united, at, or near, the point of connection of the proximal segment of the limb; so that they may be said to radiate from this point.

Composition of Scapular arch.

In the Scapular Arch the three components are named *Scapula, Clavicle* and *Coracoid.* The scapula is always present. The clavicle, when present, is a separate bone; but it is absent in many mammals, and in some Birds and Reptiles. In most Birds, and in some Reptiles, the clavicles of the two sides meet in the middle line so as to complete the under part of the osseous belt of the scapular arch. In other animals the inner ends of the clavicles rest upon the sternum. Externally the clavicle is connected with the coracoid or with the coracoid and scapula (Birds), with the acromion (most Mammals), with the coracoid (Bradypus), or with the humerus (Mole). The Coracoid is present as a separate element in most ovipara, entering into the formation of the shoulder-joint and running from it, inwards, to the sternum, in a line more or less parallel with that of the clavicle. In the Apteryx and Crocodile it forms the only bond of union between the scapula and the

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[1] In Muræna there is a scapular arch but no pectoral fin; and in Anguis the sternum, clavicles and scapulæ are present, but no other rudiment of fore limbs. In both Muræna and Anguis traces of the pelvic arch are present, suspended in the flesh. In Anguis they are connected by simple muscles to the short ribs of the caudal vertebræ; and in this animal there is a rudimentary limb consisting of a single osseous style. In common Serpents and in Lampreys the scapular arch is wanting as well as the limbs. In Cetaceous animals traces of the innominate bones are found (the ischium in the Whale, and the ischium and ilium in the Dugong), though the other bones of the posterior extremities are wanting.—Owen, *On the Nature of Limbs*, pp. 14 and 20.

sternum, the clavicle being absent. In FISHES it often forms a great part of the arch, and completes it beneath by meeting its fellow of the opposite side. MONOTREMES are the only members of the mammalian class in which the coracoid remains as a distinct bone and reaches the sternum. In the other members of the class it is early ossified to the scapula, and forms a mere process projecting a short distance from the neighbourhood of the glenoid cavity; in some it can scarcely be said to constitute a distinct element at all.

Its position.

Wherever a thorax is present, and is separated from the head by a neck, the scapular arch is situated, behind the neck, at the anterior part of the thorax; and usually it is connected, by means of the clavicle, or coracoid, or by both, with the sternum. In CHELONIANS (Pl. III. fig. 10) the scapulæ are received within the thorax, and are usually joined, or connected, with the anterior two thoracic ribs, which is for the purpose of rendering the fore limbs more efficient to carry the ponderous carapace. The scapular arch in these animals is not directly jointed to the sternum[1]. In many FISHES, there being no neck and the thoracic organs being received into the head, the scapulæ are articulated with the hinder part of the cranium, which, in these animals, may be said to form the fore part of the thorax. In SHARKS and RAYS, however, the scapulæ are joined to the spines of the vertebræ, at some distance behind the head; and they occupy, therefore, a position more nearly corresponding with that which they hold in other animals.

Composition of the Pelvic arch.

The three bones which compose the Pelvic Arch, on either side, are the *Ilium*, the *Ischium* and the *Pubes*. They are all three usually present. In FISHES, however, the pelvis is represented by a single bone, which is joined to its fellow of the opposite side; and in CETACEANS there are only one or two bones, on each side; they are of cylindrical shape, and are connected with one another, and with the rest of the skeleton, only by muscles. In all other MAMMALS, as well as in BIRDS and most REPTILES, the three pelvic bones are present and are united together at the acetabulum, forming the *os innominatum;* this is articulated with the sacral vertebra, or vertebræ, and affords a firm means of transmitting the weight of the trunk to the hinder limbs. Usually the pelvic ring is completed below, and the pelvic viscera are encircled, owing to the approximation of the pubic bones in the middle line and their connection with one another at the symphysis. The ischiatic bones usually run forwards from the acetabula, and become united with the pubic bones, so as to surround, with them, the *obturator foramina*, and separate the foramen of one side from that of the other. In MONOTREMES and CROCODILES (Pl. III. figs. 5 and 6, 19'), however, the ischiatic bones do not run forwards to the pubes, but are connected with each other in the middle line in the same manner as the pubic bones; hence the obturator foramen

[1] The anterior division of the triradiate scapular apparatus descends, however, to the inner surface of the sternum. It appears to represent the clavicle; still it is not separate from the scapula, and its connection with the scapula led Cuvier (*Leçons d'Anat.* I. 361) to regard it as a prolonged acromion. It is probably ankylosed with the scapula for the purpose of giving strength, which is required in consequence of its other end not being closely connected with the sternum; just as we find that where the coracoid reaches the sternum it remains a separate bone, and where it does not do so it becomes early united to the scapula.

M. Gervais, *Annales des Sciences*, XX. 64, finds that the scapula in chelonians is articulated not, as usually stated, to the vertebral column but to the ossified dermal skeleton in front of the first rib. This is so in some turtles (Chelonia imbricata, Mydas, &c.); but in many land-tortoises the scapula is distinctly united, either directly or by intervening ligament, with the first rib, or more commonly with the conjoined distal ends of the first two dorsal ribs.

is one broad fissure extending across the pelvis, instead of being divided into two. This is the case in some TORTOISES. In other CHELONIANS the pubic and ischiatic bones neither reach the middle line, nor are they united to one another; the obturator foramina are, consequently, not closed below. In BIRDS the iliac bones have an extensive connection with the vertebral column; and the pelvic arch is incomplete beneath, there being a more or less considerable interval between the ossa innominata of the two sides. Nevertheless the anterior extremities of the pubic and ischiatic bones of each side are commonly united, forming circles around the obturator foramina.

Differences between scapular and pelvic arches.

The chief differences between the scapular and the pelvic arches, therefore, consist in the greater fixity, as well as the greater size, of the latter; and these features of the pelvic arch have relation to the larger dimensions of the hinder limbs and to the greater force which is exerted by them in propelling, as well as in supporting, the trunk. Where, as in FISHES, the fore limbs have more locomotive office than the hind limbs, we find that the scapular arch is larger and more fixed than the pelvic arch.

Homology of ilium with scapula;

There is no difficulty in recognising in the *ilium* the homologue of the *scapula:* and, in accordance with the principles upon which the comparison of the limbs has been made in these pages, I regard the anterior margin of the ilium as corresponding with the posterior margin of the scapula, and the upper and lower anterior spines of the ilium as corresponding respectively with the posterior angle of the scapula and the rough space for the attachment of the long head of the triceps. The crest of the ilium thus corresponds with the upper (in man posterior) margin of the scapula; the Epiphysis formed upon the latter, which is sometimes expanded into the *suprascapular* bone (Pl. III. fig. 11, s.s.), corresponds with the Epiphysis formed upon the crest of the ilium; and the posterior edge of the ilium—that is, the sacral and sacro-sciatic edge—corresponds with the anterior (in man superior) margin of the scapula.

of the ischium and pubes with the clavicle and coracoid.

The following out of the same process of comparison leads also to the conclusion that the *ischium* or hinder bone of the pelvis, is the homologue of the *clavicle*—or anterior bone of the scapular arch—, and that the *pubes* is the homologue of the *coracoid;* and it will be found that many points in the anatomy of the bones and of the soft parts harmonize with this view. Thus the outer edge of the sacral margin of the ilium, which probably corresponds with the spine of the scapula, and which gives origin to the *glutæus*—the homologue of the *deltoid*—, is connected, by means of the sacrosciatic ligaments, and in some animals (BIRDS, SLOTHS and ARMADILLO) by means of a plate of bone, with the ischium: the *adductor longus*, which appears to be the homologue of the *pectoralis major,* arises from the outer surface of the ischium: the *iliacus* muscle, the femoral artery, and the anterior crural nerve descend upon the anterior surface of the pubes; and the homologues of these—the *subscapularis* muscle, the axillary artery, and the brachial nerves—descend close behind the coracoid; the *coraco-brachialis* runs from the middle of the humerus to the tip of the coracoid; and its homologue—the *adductor longus*—runs from the middle of the femur to the spine of the pubes[1].

[1] Meckel, *Handbuch der Menschlichen Anatomie,* I. 289, says that the ilium corresponds with the blade of the scapula, the body of the pubes with the coracoid, and the horizontal ramus of the pubes with the outer part of the clavicle; that the

Pelvis and scapula probably participate in the rotation of the limbs during development.

It has already been remarked that the upper parts of the ilium and the scapula become inclined towards one another during development; and it is probable that they also participate, to some extent, in the rotation which the limbs undergo. That is to say that at first they are simple, straight, vertically placed elements; and that the corresponding parts, viz. the hinder edge of the scapula and the anterior edge of the ilium, like the surfaces of the limbs of which they are a continuation, are originally directed more or less outwards, and subsequently become turned towards one another. I am not aware that any such change has been actually traced: but it is suggested by an examination of the parts, especially of the scapula, in Monotremes, Birds, and Reptiles. In the Ornithorhynchus, more particularly, the hinder edge of the scapula has an inclination outwards, and the spine is turned forwards and forms the anterior margin of the scapula. Such a theory of the rotation of the scapula on its vertical axis accords also with the mode in which, in Mammals, the clavicle and acromion usually cross over the coracoid process.

RELATIONS OF THE SCAPULAR AND PELVIC ARCHES TO THE REST OF THE SKELETON.

In endeavouring to trace the relations of the Scapular and Pelvic Arches and their appendages—the Limbs—to the rest of the vertebrate system, we have, first, to inquire from what parts, if any, of a vertebra, or vertebræ, are they produced; and, secondly, to which of the vertebræ do they belong. On neither of these points is it easy to give a decided opinion; and on neither of them are the able anatomists who have directed their attention to the subject by any means agreed.

Scapular and Pelvic arches appertain to the Visceral system.

It has been already remarked that both the scapular and pelvic arches are, in part, subservient to the visceral system as well as to the limbs, and that they are present in certain animals where the limbs are wanting, and that the same thing is occasionally observed in the human subject. They cannot, therefore, be regarded as mere dependencies on the limbs—in other words, as centripetal productions radiating, as some anatomists maintain, from the attached parts of the limbs, towards the anterior and posterior aspects of the trunk. They must rather be considered as appurtenances to the trunk, modified in a peculiar manner with reference to the limbs; and this makes it probable that they are evolved from certain of the visceral—"hæmal"—elements of one or other of the vertebræ—a view which is, I think, confirmed by an examination of the relations of the *ossa innominata* to the caudal hæmal arch, on the one hand, and to the inferior elements of the visceral arches of the trunk, on the other, in the different classes of animals. If, for instance, we compare the Mole, "where the pelvic arch is reduced, in its transverse dimensions, to the ordinary size of the hæmal arches in the tail, and where it surrounds only the

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body and descending portion of the ischium correspond with the acromion, and the ascending ramus with the fore part of the clavicle.

Dugès, as before remarked, see footnote 1, page 15, had a clearer conception of the homology of these bones.

The antagonistic relations of the pelvis and scapula to each other are well marked in the Mole, in Sloths, in the Armadillo and in some Rodents.

pelvic continuation of the aortic arterial trunk[1]," with those animals, as the Bat and the Bird, where the pelvis partially encloses the viscera as well as the artery, and, lastly, with those animals, as the greater number of Mammals and Reptiles, where the ossa innominata, in combination with the sacrum, form a complete girdle investing all the viscera and vessels of the hinder part of the trunk, with the exception of the testes and their vessels, we cannot fail to perceive that the pelvic arch is formed, in part at least, by a modification of those vertebral elements which constitute the hæmal arches of the tail. And the corresponding homologous relations of the pelvic bones with the hæmal arches of the trunk are equally manifested by the disposition of the parts in the skeleton of the Alligator, to which reference will again shortly be made.

The pelvic bones are developed in the ventral lamina of the primordial vertebral system, as it is passing down to enclose the viscera of the embryo; they are spread out in this lamina, and contribute to form the walls of the thoracico-abdominal cavity. Now the parts of the vertebral system which appertain to this lamina are the so-called (by Professor Owen and most other anatomists) "pleural" and "hæmal" parts. The scapulæ and iliac bones are usually regarded as modifications of the pleural elements or ribs; and the clavicles, coracoids, pubic and ischiatic bones as modifications of the hæmal elements. Moreover, Prof. Owen recognises in the diverging processes of the ribs of birds the representatives of the limbs.

Arguments against the view that the Scapulæ and Iliac bones are ribs; their positions are different;

To these views of the homology of the scapular and pelvic arches and of the limbs it may be objected—First, the ribs are offsets from the transverse processes of the vertebræ, are formed in close contact with them, and always remain connected with one or both of them[2]; whereas the scapulæ, in most instances, and the iliac bones in some (Whales and Dolphins), are formed, and remain, quite separate from the transverse processes, having only a very indirect connection with them; and parts which differ so widely in their development and connections can scarcely be said to be homologous.

scapulæ and ilia coexist with ribs;

Secondly, the ribs, or bones corresponding with them, are, in many instances, present in the regions answering to the limbs, and are, then, quite independent of, and, it may be, quite separate from the scapulæ and the iliac bones. Thus in the Alligator and many Reptiles distinct ribs extend all along the neck to the skull. This will, it is true, be no difficulty with the homologists who conceive that the scapular arch is an appendage to the skull. But it must be added that the alæ of the sacrum are very often, if not usually, also developed from separate nuclei; and these may fairly be presumed to be the ribs of the sacral vertebræ. Indeed, the example of the Menopoma (Pl. III. fig. 12) proves that they are so; for, in that animal, the ribs extend, as distinct elements, to the pelvis, and the iliac bones are attached to the extremities of these ribs. In many Chelonians also the ribs to which the iliac bones are connected, as well as those to which the scapulæ are attached, are quite distinct. One of the arguments which Owen adduces in favour of his view that the scapular arch is an appendage to the occipital vertebra is derived from the

[1] Owen, *On the Nature of Limbs*, p. 19.

[2] The "floating ribs" are no exception to this, inasmuch as the articular part upon which they rest is a rudimentary inferior transverse process.

fact that, in the crocodile, the "pleurapophyses"—or ribs—are developed upon the transverse processes of each of the cervical vertebræ; and, therefore, that the scapula (which he regards as a pleurapophysis) cannot belong to either of these vertebræ. Yet in the case of the sacral vertebræ, in the reptiles just mentioned, and in other instances, where precisely the same difficulty exists, it is assumed that the pleurapophysis is compound, the ilium forming one part, and the wing of the sacrum forming the other part. Surely if this hypothesis of the constitution of the pelvic circle be true, it would apply to the scapular arch; if the ilium be only half a pleurapophysis, the blade of the scapula, which is unquestionably the homologue of the ilium, must be half a pleurapophysis also, and may as reasonably be referred to the cervical vertebræ as the ilium is referred to the sacral vertebræ. I think any one who will take the trouble to compare the figures of the occipital with the pelvic vertebræ of the Amphiuma and Lepidosiren which are given in Pl. I. of the *Discourse on the Nature of the Limbs*, will come to the conclusion that either the ilium and the scapula are not homologous, or that there is some fallacy in the view which the learned author of that "Discourse" maintains with regard to the relation of those bones to their respective vertebræ. The inconsistency is entirely avoided, and the constitution of both the scapular and the pelvic arches are explained and harmonized, by the hypothesis given above, that they are both derivatives entirely from the hæmal parts of the vertebræ.

difference in development;

Thirdly, in the process of its development, the scapular arch does not appear to grow downwards, like the ribs, from the vertebral axis, but to be first formed near the lower part of the descending ventral lamina—that is, at the lower edge of the visceral portion of the vertebral system; thence it grows, upwards, towards the spine, and, downwards, towards the inferior mesial plane of the embryo. That the same thing is not so apparent in the pelvic arch, probably results from the fact that the transverse and pleural elements of the vertebræ are shorter in the sacral than in the thoracic region; and the primordial structures of the pelvis are, therefore, laid down in closer proximity to the vertebral column than are those of the scapular arch.

Diverticula of bird's rib do not answer to limbs.

Fourthly, the diverticulum of the bird's rib does not correspond in position with the fore limb, even according to the view of those who regard the scapula as the homologue of a rib; for it grows out, not from the point of junction of the pleural with the hæmal elements, but from the shaft of the rib. It seems rather deserving to be considered as a process formed, like so many others in the thorax of these creatures, for the purpose of giving attachment to muscles, and of rendering the chest a firm basis for the wings[1].

The scapulæ and ossa innominata altogether *hæmal.*

I cannot but think that a more correct view of the homological relations of the scapular and pelvic arches may be derived from an examination of the skeleton of the ALLIGATOR (Pl. III. figs. 4 and 5). In that animal the hæmal parts of the vertebræ form a continuous series of bones extending along the floor of the thorax and abdomen to the pelvis. Two bones on either side (*h* and *lh*)—a mesial and a lateral bone—corresponding with each vertebra, are placed end to end. In the thorax

[1] In the Lepidosiren the diverging appendage is not connected with the scapula at all, but is attached wholly to the coracoid. —Owen, *On the Nature of Limbs*, p. 52.

they extend from the sternum to the ribs. In the abdomen they run, from the middle line, transversely or obliquely outwards, but they do not reach the transverse processes or the ribs. They are continued quite down to the pelvis; and the pelvis seems obviously to form a continuation of the series, the pubes and ischium of either side being the mesial hæmal bones, widened and thickened to give strength to the pelvic arch, and the ilium being a lateral hæmal bone which has undergone still greater expansion. The position and appearance of the scapular arch is also in accordance with the same view, the broad coracoid being a mesial hæmal bone and the scapula a lateral hæmal bone.

Number of hæmal elements in scapular and pelvic arches.

On the whole I think the probability is in favour of the opinion that each of the mesial components of the scapular and pelvic arches is formed by one mesial hæmal bone and not by two or more conjoined. The blade of the scapula[1] (including the spine) and the ilium may each, perhaps, be regarded as the representative of two lateral hæmal bones, and may be supposed to appertain to the two mesial bones from which the coracoid and the clavicle, in the one case, and the pubes and the ischium, in the other, are developed. Such a view is not improbable, although each is, from the first, single. If this be so the relations of the scapula to the coracoid and the clavicle in the several vertebrate classes indicate that the hinder and chief parts of the blade of the scapula appertain to that hæmal arch from which the coracoid is produced, and that the spine of the scapula forms a part of the same hæmal arch with the clavicle. The relation of the parts of the ilium to their respective hæmal bones is not so clear, because in nearly all vertebrates the three bones—ilium, ischium, and pubes—are united into one at the acetabulum[2]. This results from the ischium stopping short at the acetabulum, instead of being continued on to a distant part of the ilium. A disposition nearly analogous to this is met with in the scapular arch in the case of the MOLE and of those BIRDS, in which the clavicle does not extend beyond the shoulder-joint. It must be observed, however, that often the ischium is connected, by means of the sacro-sciatic ligaments, with the hinder edge of the ilium—the part which seems to correspond with the spine of the scapula—and in some instances (BIRDS, the ARMADILLO, and SLOTHS) this connection is established by a continuity of bone. In such cases a resemblance may be seen to the disposition of the parts in those BIRDS in which the clavicle extends, beyond its connection with the coracoid at the shoulder, on to the dorsum of the scapula. This question, however, of the number of hæmal elements, which are concerned in the formation of the several parts of the scapular and pelvic arches is a matter of secondary importance.

It may be observed that the uniformly close connection which the components of the scapular and pelvic arches respectively bear to one another is a strong argument that they belong altogether to the same division of the vertebral system—that one bone does not appertain to the transverse or pleural segment of a vertebra and the others to the hæmal group, but that all of them are either pleural or hæmal elements; and the various points which have been mentioned above appear to me to be very strongly in favour of their hæmal character.

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[1] Oken conceived the scapula to be a compound of five cervical ribs.

[2] In the Alligator (Pl. III. fig. 5) the pubes runs to the ischium and scarcely touches the ilium.

Pelvic arch appertains to sacral vertebræ.

Assuming that the scapular and pelvic arches are developed from the hæmal parts of the vertebral system, it remains to be determined to which of the vertebræ they more particularly belong. In the upper three classes of the vertebrate order of animals their position is remarkably uniform. They evidently appertain to the trunk; the scapular arches being placed at the fore part of the trunk and the pelvic arches at the hinder part, so as to be in the most favourable position for transmitting the weight to the limbs. The pelvic arch is, moreover, articulated closely with the hindmost two or three vertebræ of the trunk, which are usually more or less ankylosed together forming the sacrum. Not only is the pelvis situated and developed at this region; but it, as well as the limbs which are appended to it, derives its nerves from the part of the spinal cord which corresponds with, and which originally occupied, the sacral region of the vertebral canal. We have, therefore, no difficulty in referring the pelvic arch and limbs to one or more of the sacral vertebræ.

Scapular arch appertains to vertebræ near fore part of trunk,

In the case of the scapular arch, the arguments in favour of its belonging to the vertebræ, at or near the anterior part of the trunk, seem to me almost as decisive as those which induce us to refer the pelvic arch to the sacral vertebræ. The scapular arch, I grant, is not usually so closely connected with any particular vertebræ; and it is sometimes attached to the rest of the skeleton only by muscles. We have not, therefore, so definite a guide to its exact relations as in the case of the pelvic arch. Nevertheless all the other reasons which lead to the conclusion that the pelvic arch belongs to the hinder part of the trunk are equally strong in favour of the view that the scapular arch appertains to the fore part of the trunk. Thus—the scapular arch in all animals, with the exception of certain Fishes, is situated near the anterior region of the chest; in many animals it is articulated with the sternum; and in some it is articulated with the anterior dorsal vertebræ; it is developed in the immediate neighbourhood of the fore part of the chest; it derives its supply of nerves from the part of the spinal cord which corresponds with this region; and its muscles are attached all round about this region, quite as many passing from it backwards towards the abdominal and pelvic regions as forwards towards the head.

According to Wagner[1], the extremities appear in the chick, during the second half of the third day, upon the exterior of the primordial structure for the ribs. At this time there is scarcely any neck, so the ribs are close behind the cranial visceral arches. Subsequently —at about the 7th day—the neck becomes developed[2]; and the chest and fore limbs are thereby distanced from the head. It will be perceived, therefore, that the proximity of the scapular arch and the fore limbs to the head in the early embryonic periods is occasioned by the proximity of the chest to the head, and that, subsequently, in consequence of the increasing length of the neck, the head becomes distanced from both the fore limbs and the chest. It follows also that the change of position affects the head rather than the scapulæ; and that it is more correct to say that the head is at first near the shoulders, than that the latter occupy a forward position near the head.

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[1] *Lehrbuch der Physiologie*, s. 77, and *Icones Phys.*

[2] Wagner, s. 83.

not to the occipital vertebra.

In certain Fishes, however, the shoulder-blades are attached to the hinder part of the head; and the consideration of these animals has induced Professor Owen to advance the doctrine that the scapular arch and the fore limbs, throughout the vertebrate series, are appendages, not to the trunk but to the cranium, and that they form parts, not of the posterior cervical or anterior dorsal vertebræ but, of the occipital vertebra. Now, apart from the danger of making that which is obviously an exceptional instance the rule for all the members of the vertebrate series, it must be remarked that the skeleton of the fish is but an imperfect example of the vertebrate skeleton, and that it, perhaps less than that of any other animal, deserves to be adduced as a standard or typical skeleton. The Fish is destined to move and breathe in water; and its adaptation to these peculiar conditions is attended with such peculiarity of conformation, that we should be careful how we draw inferences from the anatomy of this class, with the view of applying them to other vertebrates. One of the remarkable peculiarities of the fishes in question is a want of development of neck, and a consequent close approximation of the head to the trunk[1]. The respiratory apparatus is situate beneath the cranium, under cover of the expanded visceral arches of this part; and the scapular girdle, retaining its relations with the organs of respiration, is attached to the occiput. Such position of the scapulæ, like that of the respiratory organs, is unusual; indeed it may be said to be an abnormal or imperfect condition, having relation to a want of development of the cervical portion of the skeleton; and it cannot be received, therefore, as an exponent or type of the relations of these parts to their respective vertebral centres throughout the whole of the vertebrate classes.

The same process of argument which deduces the universality of the occipital relations of the scapular arch and the fore limbs from the example of the Fish might be used in favour of a similar view with regard to the pelvic arch and the hinder limbs; for we know that the pelvic fins in certain fishes are missing from their ordinary position and are attached to the scapular arch beneath the pectoral fins, and that in some fishes they lie in a plane actually anterior to the pectoral fins.

It is highly improbable that such a shifting (actual or virtual) of an important part of the skeleton should take place as is contemplated by those who conceive that the scapular arch is normally and originally developed in connection with the occiput and has become transferred to the fore part of the chest. In some animals this would amount to a distance of nearly 30 vertebræ; and we know of no other instance of the transfer, or dislocation, of a bone from its parent vertebra at all approaching to this, neither do I know of any evidence deducible from the development of the parts which is really in favour of such a view[2].

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[1] Forasmuch as in some fishes the thoracic organs are partly enclosed in the head, and the homotypes of the sternum are admitted, by Owen as well as St Hilaire, to be combined with the bones of the head, it is not easy to perceive on what ground the former anatomist objects to the statement made by the latter, that the neck is absolutely wanting in these animals.

[2] "It is somewhat remarkable that the only embryological evidence which Professor Owen adduces in support of that portion of his Doctrine of Limbs, in which the anterior limb is assumed to be developed at or close to the head, is a reference to a passage in Rathke's *Entwickelung der Schildkröten*, in which the author adduces the *fundamental position* of the bones of the shoulder—viz. the posterior region of the neck—as a circumstance tending to explain their ultimate passage into the thoracic cavity."—Goodsir, *On the Morphological Constitution of the Limbs*. Edinburgh *New Philosophical Journal*, 1857, p. 179.

The argument that there is no other hæmal arch, except the scapular, which would complete the occipital bone, rests upon the assumption that no other view of the homology of the cranial bones is admissible, except that which requires the scapular arch to be admitted as a member of the cranial group of bones[1].

Limbs in different animals appertain to vertebræ near which they are placed.

It may be urged that, in the different families of the Piscine class, we have examples of a shifting of the position of the hinder limbs—the pelvic fins—at least equal to that which is asserted for the fore limbs in the higher vertebrates by those anatomists who would derive the scapula from the occipital vertebra. To prove the validity of this argument, however, and to show that any corresponding shifting of the ventral fins of Fishes has taken place, it is essential to determine to which of the vertebræ they really appertain, and whether they do actually appertain to any one vertebra in all the several fishes—for instance, whether the ventral fins of the PERCH are constituents of the same vertebra as the ventral fins of the COD. There does not appear to be a necessity for such an assumption; and instead of assenting to the theory of the shifting of the fore limbs in some animals, and of the hinder limbs in others, which is founded upon the view that they are the appendages of certain particular vertebræ throughout the whole vertebrate series, it seems more in harmony with the facts of anatomy to regard the limbs and their arches, in each animal, as appurtenances to those vertebræ near which they may be placed. We find, in examining the different classes of animals, that the parts of the several vertebræ are modified in accordance with the requirements of each animal; and that the general law which governs the construction, and gives uniformity to the whole vertebrate series, yields continually to the other equally pervading law, which provides adaptation to those particular purposes which the creature is intended to serve. We find, for instance, that the number of the vertebræ which enter into the composition of the skeleton, as well as into each division of the skeleton, except, perhaps, the head, varies very greatly; that the hæmal elements are present, in some animals, in regions where there is no trace of them in others; and that, in different animals, in corresponding regions, they undergo considerable variety in their modifications. It seems, therefore, only the natural inference that the modifications which we conceive to be associated with the development of limbs should take place in those vertebræ the position of which is most suited to enable the limbs to minister to the wants of the particular animal.

Laws of Unity of plan and variety of detail; how combined;

In the investigation of the anatomy of the limbs we perceive abundant and most instructive illustrations of the operation of the two great laws which have been just referred to, viz. the law of UNITY OF PLAN, which may be called the LAW OF TYPE, and the law of ADAPTATION TO PARTICULAR REQUIREMENTS. We have found that, throughout the vertebrate series, the limbs present a marked similarity in their general construction; yet that they are subject to varieties of form

[1] In a communication which I made to the Zoological Section of the British Association at Leeds, an abstract of which is published in the Reports of the Association, 1858, Pt. II. "Notices and Abstracts" p. 126, I gave reasons for thinking that the hæmal part of the occipital vertebra is formed, not by the scapular, but by the hyoid, arch. See also my *Treatise on the Human Skeleton*, p. 597.

as numerous as the various modes in which their functions have to be performed. And this grafting of an endless variety of detail upon one plan, in conformity with the endless variety of wants and feelings and offices of the several animals—this combination of variety with uniformity, in which the deviations of each form from the others are no more than are absolutely necessary to attain the required end—constitutes one of the most striking features in creation, and arrests the attention of thoughtful observers in every part of the domain of nature. Many theories have been connected with it, none of which are perhaps entirely satisfactory. We cannot doubt that the working out of variety in detail in the several parts of an animal's frame, so as to bring each part into harmony with the others and with the sensational and volitional qualities of the creature, is effected under the influence of some high controlling law; that the modifications of the limbs, for instance, in accordance with the peculiarities of the brain and the attendant wants and desires of the animal, take place in obedience to some definite principle; and that the development of any one organ bears some close relation to the development of the others; but the nature of that relation, and the manner in which the influences of the formative processes in different parts are mutually operative, are subjects which lie too deep in the mysteries of nutrition for us even to venture, at present, to speculate upon.

how related to mode of development.

The similarity which pervades the general plan of the construction of the limbs, evidently, has relation to and, perhaps, may be said to depend upon, a similarity in the plan of their development. The further we trace the fore and the hind limbs, and the limbs of various animals, back to their early embryonic forms, the closer do we find that the resemblance between them becomes, one peculiarity after another disappearing till the several distinctive features are lost in a oneness of simplicity; just as in tracing the different animals back along the paths of development we find them all reduced to one simple germ-form. Each germ is, of course, potentially different from the others, inasmuch as it is endued with the qualities requisite for the manifestation of its distinctive peculiarities; but they all start from one point; and the development of all proceeds in the same manner as far as is compatible with the ends to be attained; and they diverge from one another, in different ways, and in different degrees, to evolve the several varieties of form which are observed in the several members of the animal kingdom. Thus the cause of their similarity lies at the commencement of their career, where the different species start from a common centre of resemblance; and the several causes of dissimilarity operate with various, but on the whole with increasing, influence as the work of development proceeds.

Theory of archetype questioned.

Thus much we can perceive; but if we attempt to speculate beyond this we incur the risk of error. We can see that nature works from a simple form, and builds upon a uniform plan, as far as possible; but there seems no good reason to assume that she works up to, or with reference to, any ideal or archetypal pattern. One cannot, therefore, but entertain a doubt whether the introduction of the notion of an archetype into the minds of anatomists, and the consequent endeavour to make out that archetype, and to trace the approximations to it, and the divergences from it, in the various classes of animals, do not rather tend to lead the student from the true path of nature, and fetter rather than assist him in the comprehension and investigation of her works.

I venture upon this hint with some timidity and not without much reflection, knowing that it is in opposition to the views of one whose labours in this field exceed those of any living anatomist, and whose authority is deserving of proportionately great weight. I feel, too, an unwillingness to cast a doubt upon a great and important generalization; for generalizations give a charm and an impetus to science, and it is vexing and disappointing to find them questioned when we have nurtured them and enjoyed them and looked to them as our helps to further progress. But after all, it is by questioning and discussing, no less than by assenting, that science is to be advanced; and a theory, if true, will thereby shine forth brighter and clearer and better fitted to light men on their way.

This feeling renders me unwilling to assent to the expression that "the same type has governed the formation of the two limbs[1];" I would rather say that they are products from one simple structure, their similarities not being the result of a subjection to one pattern but of an emanation from one point under the influence of similar nutritive forces. So likewise it seems scarcely correct to speak of "the fading away of the pattern[2]," unless we have stronger ground for belief in the existence of a pattern. Again, the statement that "the archetype is progressively departed from as the organisation is more and more modified in adaptation to higher and more varied powers and actions[3]," would seem to me more correct if the term "simple primary form" were substituted for the word "archetype."

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[1] Owen, *On the Nature of Limbs*, p. 11. [2] *Ibid.* p. 15. [3] *Ibid.* p. 49.

The following tables of the Bones, Ligaments, Muscles, Arteries and Nerves, made for the purpose of comparing them in the two limbs, are taken from the Human Subject. The letter V, prefixed, signifies that the correspondence is in accordance with the plan of Vicq-D'Azyr, and the letter M with that of M. Martins.

COMPARISON OF THE
BONES OF THE UPPER AND LOWER LIMBS.

	UPPER LIMB.	LOWER LIMB.
(V. M.)	SCAPULA, BLADE of	ILIUM.
(M.)	Inferior Angle.	Anterior superior Spine.
(M.)	Roughness for tendon of *Triceps.*	Anterior inferior Spine for tendon of *Quadriceps.*
(M.)	Posterior Costa.	Crest.
	Spine and Acromion.	Ridge for *Glutæus Maximus* continued into sacro-sciatic ligament.
(M.)	Sub-acromial Notch.	Sacro-sciatic Notch.
	CORACOID process.	PUBES.
	CLAVICLE.	ISCHIUM.
(V. M.)	HUMERUS.	FEMUR.
(M.)	Great Tubercle.	Great trochanter.
(M.)	Small do.	Small do.
	Convex posterior surface of Shaft.	Convex anterior surface of Shaft.
	Concave anterior do.	Concave posterior do.
(M.)	Outer Condyle.	Inner Condyle.
(M.)	Inner do.	Outer do.
(M.)	Anterior aspect of Articular Surface.	Posterior aspect of Articular Surface.
	RADIUS.	TIBIA.
	Styloid process.	Inner Malleolus.
	Anterior surface (in the state of pronation).	Anterior surface.
	ULNA.	FIBULA.
	Styloid process.	Outer Malleolus.
(V. M.)	Epiphysis of Olecranon.	PATELLA.
(V. M.)	SCAPHOID.	SCAPHOID.
	SEMILUNAR.	ASTRAGALUS.
(V. M.)	CUNEIFORM.	OS CALCIS.
(V. M.)	PISIFORM.	Epiphysis at heel.
(V. M.)	TRAPEZIUM.	CUNEIFORM, INTERNAL.
(V. M.)	TRAPEZOID.	Do, MIDDLE.
(V. M.)	MAGNUM.	Do, EXTERNAL.
(V. M.)	UNCIFORM.	CUBOID.
(V. M.)	METACARPALS.	METATARSALS.
(V. M.)	PHALANGES.	PHALANGES.
	First and third (ungual) of Pollex.	First and third (ungual) of Pollex.
	First, second, and third (ungual) of Fingers.	First, second, and third (ungual) of Toes.

Vicq-D'Azyr, Martins, and most anatomists, regard the Clavicle as the homologue of the Pubes, and the Coracoid of the Ischium. Vicq-D'Azyr considers the Ulna to be the homologue of the Tibia, the Radius of the Fibula, and the Astragalus of the Semilunar bone together with the head of the Os Magnum. M. Martins regards the Tibia as representing the Radius and the sub-olecranon portion of the Ulna.

COMPARISON OF THE

LIGAMENTS[1] OF THE UPPER AND LOWER LIMBS.

UPPER LIMB.	LOWER LIMB.
SCAPULAR.	PELVIC.
Proper	
Coraco-acromial.	
	Sacro-iliac.
SCAPULO-CLAVICULAR.	
Acromio-clavicular?	Sacro-sciatic.
Coraco-clavicular?	Obturator.
SHOULDER.	HIP.
Capsular.	Capsular.
Accessory (with space for *Subscapularis* tendon between them).	Accessory (with space for *Iliacus* tendon between them).
Glenoid.	Cotyloid.
Fibres passing over glenoid notch.	Transverse, over cotyloid notch.
Gleno-humeral.	Teres.
ELBOW.	KNEE.
Lateral external.	Lateral internal.
Lateral internal.	Lateral external.
Anterior.	Posterior.
Posterior.	
	Crucial.
	Semilunar Cartilages.
Orbicular?	Peroneo-tibial, anterior and posterior.
WRIST.	ANKLE.
Lateral external.	Deltoid.
Lateral internal.	Lateral external.
Anterior.	Posterior.
Posterior.	Anterior.
(N. B. The terms "External" and "Internal," as well as "Anterior" and "Posterior," should, strictly speaking, be reversed, because the thumb forms properly the *inner* edge of the hand).	
Triangular.	Inferior interosseous.
	Peroneo-tarsal.

[1] None of the authors, whose writings I have seen, point out the correspondence of the Ligaments in the two limbs.

COMPARISON OF THE

MUSCLES OF THE UPPER AND LOWER LIMBS.

	UPPER LIMB.	LOWER LIMB.
	FROM TRUNK TO SCAPULAR ARCH.	No distinct parallels, the Pelvic arch not being moveable upon the trunk. The nearest are probably the muscles developed in the abdominal wall and passing from the thorax and spine to the crest of the ilium.
	Trapezius.	
	Rhomboideus major.	
	Do. minor.	
	Levator anguli scapulæ.	
	Serratus magnus.	
	Pectoralis minor.	
	FROM TRUNK AND SCAPULAR ARCH TO HUMERUS.	FROM TRUNK AND PELVIC ARCH TO FEMUR.
(V.M.)	Pectoralis major, and minor (from clavicle continued *back*wards upon side of chest, the circle formed by clavicle and coracoid being incomplete).	Adductor magnus, brevis, and Pectineus (from Ischium continued *for*wards along the complete circle of Ischium and Pubes).
(V.M.)	Deltoid.	Glutæus maximus.
(V.M.)	Subscapularis.	Iliacus internus.
	Latissimus dorsi? (from spine to humerus; draws arm *back*wards, i. e. flexes shoulder[1]).	Psoas Magnus (from spine to femur; draws thigh *for*wards, i. e. flexes hip).
	Coraco-brachialis (from end of coracoid to middle of humerus; adducts arm).	Adductor longus (from spine of pubes to middle of femur; adducts thigh).
	Short muscles of Shoulder.	Short muscles of Hip.
	Supra-spinatus; Infra-spinatus; Teres minor.	Obturators; Glutæus medius and minimus.
	Teres major corresponds in its origin with	Sartorius and Tensor vaginæ femoris.
	EXTENSORS OF FOREARM.	EXTENSORS OF LEG.
(V.M.)	Triceps. (including Anconeus[2]).	Quadriceps.
	FLEXORS OF FOREARM.	FLEXORS OF LEG.
(V.)	Biceps—long head.	Biceps—long head.
		Semimembranosus.
		Semitendinosus.
	—short head[3]?	Gracilis.
(M.)	Brachialis anticus.	Biceps—short head[4].

[1] In the TORTOISE the latissimus arises from the interior of the carapace and runs to a fossa near the base of the lesser tubercle of the humerus. In that animal, however, there is no psoas; and, it must be confessed, the homological relation of these two muscles is quite open to question.

[2] M. Martins suggests that the Anconeus corresponds with the Ligamentum Patellæ. Vicq-D'Azyr regards it as the correspondent of the Pronator teres.

[3] The origin of the short or internal portion of the Biceps, its close relation to the coraco-brachialis in animals where it exists, and the fact that it is given off as a slip from the latter in the BEAR, indicate that this part of the biceps belongs to the group of adductors of the arm; and the gracilis is the only one of the adductors of the thigh which extends to the leg.

[4] In many mammals the biceps has extensive connections with the fascia of the leg; in some the femoral portion is wanting; in some it is a separate muscle.—Cuvier, *Leçons d'Anat. Comp.* I. 520.

	Muscles of Forearm and Hand.	Muscles of Leg and Foot.
(M.)	Pronator teres.	Poplitæus.
(M.)	Flexor carpi radialis.	Tibialis posticus.
(V.M.)	.... ulnaris.	Gastrocnemius, outer head.
(M.)	Supinator radii longus?	.... inner head.
(V.M.)	Palmaris longus.	Plantaris.
		Soleus.
(M.)	Flexor digitorum sublimis.	Flexor digitorum brevis.
(M.)	.... profundus.	.... longus.
(M.)	.... pollicis longus.	.... pollicis longus.
	Extensor carpi radialis longior .... brevior	Tibialis anticus.
	.... ulnaris	Peronei.
(M.)	.... digitorum longus.	Extensor digitorum longus.
	Extensores pollicis.	Extensor longus pollicis.
	One of the Extensores Pollicis, the Extensor indicis and the Extensor minimi digiti.	Extensor brevis digitorum.

Muscles moving radius upon Ulna.

Pronator quadratus.

Supinator brevis.

These muscles may be arranged into the following groups.

First. Those muscles of the upper limb which have no parallels in the lower limb. These all assist in the execution of movements to which there are no correspondents in the lower limb; such as the movements of the scapula upon the trunk and of the radius upon the ulna. The muscles more especially devoted to the latter office are the pronator quadratus and the supinator brevis. All the other pronators and supinators have the additional office of acting upon the elbow-joint, and have more or less distinct representatives in the lower limb.

Secondly. Those muscles which, in their connexions and functions, so far correspond in the upper and lower limbs, that their homology scarcely admits of a doubt. Such are; the Subscapularis and Iliacus; the Deltoid and Glutæus; the Triceps extensor Ulnæ and the Quadriceps extensor cruris; the Pronator teres and the Poplitæus; the Flexor profundus digitorum Manus and the Flexor longus digitorum pedis.

Thirdly. Those muscles which correspond only partially in the upper and lower limbs, and respecting the homology of which more or less doubt may be entertained. Such are the short muscles of the shoulder and of the hip; the flexor muscles of the elbow and of the knee; and some of the muscles of the forearm and of the leg.

The differences in disposition are such as, in each instance, to adapt the muscles to the functions of the respective parts. Thus, in the case of the flexors of the *elbow,* one is attached to the *fore*part of the ulna, so as to act effectively in bending it upon the humerus; and the other is attached to the *inner*, or opposed, side of the radius, so as to combine the power of supinating the radius upon the ulna with that of bending it upon the humerus. In the case of the *knee*, however, the flexors (Sartorius, Gracilis, Semitendinosus, Semimembranosus and Biceps), descending from the three projecting points (ant. sup. spine, symphysis pubis, and tuber ischii) of the pelvis, so as to give the greatest amount of power and range to the movements of the limb, pass to either side of the joint, and are attached to the *lateral* margins of the tibia and fibula, for the purpose of effecting the movement of pronation and supination of the two bones together upon the femur. In the middle segments of the limbs a different disposition prevails. The masses of muscles on the plantar aspect of the *leg con*verge to the os calcis so as to perform the difficult work of raising the heel; whereas the muscles of the palmar aspect of the *forearm di*verge towards the margins of the wrist so as to effect the movements of abduction and adduction, as well as those of flexion, of the hand. Moreover, the muscles of the thumb and fingers, for the purpose of giving strength, and in consequence of the limited surface afforded by the carpus, have

extensive attachments to the bones of the forearm; whereas some of their homologues in the lower limb (the short flexors and extensors of the toes) are confined altogether to the foot, and the tarsus affords ample space for their attachment.

The correspondence of the muscles of the Foot and Hand need not be given in detail.

COMPARISON OF THE

ARTERIES OF THE UPPER AND LOWER LIMBS.

	UPPER LIMB.	LOWER LIMB.
	SUBCLAVIAN.	COMMON ILIAC and upper part of EXTERNAL ILIAC.
(V.)	Internal Mammary (*de*scends in anterior wall of Trunk towards Umbilicus).	Internal Epigastric (*as*cends in anterior wall of Trunk towards Umbilicus).
(V.)	Supra-scapular (through Sub-acromial notch to muscles on dorsum of Scapula).	Glutæal (through Sacro-sciatic notch to muscles on dorsum of Ilium).
	Thyroid Axis.	Internal iliac.
	AXILLARY and BRACHIAL.	Lower part of EXTERNAL ILIAC and FEMORAL.
(V.)	Thoracic (between clavicle and coracoid to Pectoral muscles).	Obturator (from Int. Iliac between Ischium and Pubes to Adductor muscles).
(V.)	Subscapular (along *hinder* surface of Coracoid, Shoulder-joint and edge of Scapula, towards inferior angle of Scapula, supplying Subscapularis and muscles on dorsum of Scapula).	Circumflexa ilii (along *anterior* surface of Pubes, Hip and edge of Ilium, towards ant. sup. Spine of Ilium, supplying Iliacus internus and muscles on dorsum of Ilium).
	Circumflexa anterior (between *front* of Humerus and Flexors of Elbow to Shoulder-joint, Deltoid, &c.)	Circumflexa interna (between *back* of Femur and Flexors of knee to Hip-joint, Glutæus, &c.)
	Circumflexa posterior (between *back* of Humerus and Extensors of Elbow to Deltoid, &c.)	Circumflexa externa (between *front* of Femur and Extensors of knee to Glutæus, &c.)
	Profunda superior (between *back* of Humerus and long head of Triceps to Triceps).	Branches of Profunda femoris (between *front* of Femur and long head of Quadriceps to Quadriceps).
	Profunda inferior (runs *back*wards, towards Elbow, from Brachial, as latter passes from coraco-brachialis towards *front* of Elbow.	Anastomotica Magna (runs *for*wards, towards knee, from Femoral, as latter passes from Adductor longus into Ham).
	ULNAR[1].	POSTERIOR TIBIAL.
	Interosseous Anterior (on palmar surface of Interosseous membrane to deep muscles, then through interosseous membrane to dorsum of carpus).	Peroneal (on plantar surface of interosseous membrane to deep muscles, then through interosseous membrane to dorsum of tarsus).
	Interosseous Posterior (to muscles on dorsum of Forearm).	Muscular branches of Anterior tibial.

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[1] Vicq-D'Azyr considers that the Peroneal corresponds with the Radial, and the Anterior and Posterior Tibial with the Ulnar and Interosseous. M. Martins thinks that the Posterior Tibial corresponds with the Radial, and the Peroneal with the Ulnar. Mr Nunn, *Observations and Notes on the Arteries of the Limbs*, p. 18, suggests that the Anterior and Posterior Tibial correspond with the Interosseous arteries, and the Anastomotica Magna of the Femoral with the Radial. The latter suggestion is grounded upon the observation that in Monkeys the Anastomotica passes to the foot, the Anterior Tibial being small and having a distribution limited to the leg.

Superficialis Volæ and Superficial palmar arch.	Internal Plantar and small superficial Branches of Ulnar.
Deep palmar arch (across metacarpus, between ends of Ulnar and Radial Arteries).	Plantar arch (across metatarsus, between ends of Posterior and Anterior Tibial arteries).
RADIAL.	ANTERIOR TIBIAL.
Dorsal arteries of hand.	Dorsal arteries of foot.
Communication with deep palmar arch.	Communication with plantar arch.

The correspondence of the arteries in the two limbs, like that of the bones, is closer than the correspondence of the muscles. The chief difference depends upon the fact that the Radial artery does not usually pass to the anterior (dorsal) aspect of the limb till near the wrist, and then does so by curling round the lower end of the radius or the side of the wrist-joint; whereas its correspondent—the Anterior tibial—passes to the anterior aspect of the leg, near the knee, by perforating the interosseous membrane. It results from this, that a distinct vessel—the posterior interosseous—is given off, either from the ulnar or from the anterior interosseous, near the elbow, and passes to the dorsal aspect of the forearm to supply the muscles, the homologues of which, in the hinder limb, derive their blood from the branches of the anterior tibial. It will be observed also that in the foot there is no superficial plantar arch. The whole supply of blood is conveyed through the external plantar artery, which lies deep in the sole, protected from the pressure resulting both from the flexor tendons and from the bearing of the foot upon the ground; whereas, in the hand, the bones run straight from the forearm, and the vessels lie chiefly upon the superficial aspect of the tendons, so as to avoid the risk of interference with the current, which would have resulted had they been placed between the tendons and the bones. This provision is the more important in consequence of the contractions of the muscles of the forearm being often long continued as well as powerful. Two or more of the branches of the brachial sometimes come off by a common trunk; and this corresponds with the profunda femoris.

COMPARISON OF THE

NERVES OF THE UPPER AND LOWER LIMBS.

UPPER LIMB.	LOWER LIMB.
SUPRA-SCAPULAR and CIRCUMFLEX } to short muscles of Shoulder, to Deltoid, and Skin.	GLUTÆAL and lesser SCIATIC. } to short muscles of Hip, to Glutæus maximus, and Skin.
SUBSCAPULARIS (to Teres Major, Latissimus dorsi and Subscapularis).	Branches of Lumbar plexus to Psoas and Iliacus.
THORACIC, INTERCOSTO-HUMERAL, and INTERNAL CUTANEOUS (to Pectoral muscles and skin).	OBTURATOR (to Adductor-muscles and skin).
MUSCULO-CUTANEOUS (to Coraco-brachialis, Biceps, Brachialis anticus, and skin).	Branches of SCIATIC (to Flexor muscles of thigh and skin).
RADIAL[1] (to Triceps, Extensors, and Supinators of hand and fingers, and to Skin of dorsum of arm, forearm, and hand).	ANTERIOR CRURAL and PERONEAL (to Triceps, to Extensors of foot and toes, and to Skin of front of knee and foot).

[1] Vicq-D'Azyr regards the Popliteal as the correspondent of the Median and the Radial, and the Peroneal of the Ulnar. M. Martins coincides generally with this view, but makes the relations more complicated.

MEDIAN (to some muscles and part of skin on palmar aspect of forearm and hand, and to digits I. II. III. and half of IV.).	Branches of POSTERIOR TIBIAL, including INTERNAL PLANTAR (to some muscles and part of skin of plantar aspect of leg and foot, and to digits I. II. III. and half of IV.).
ULNAR (to some muscles and part of skin on palmar aspect of forearm and hand, and to digit V. and half of IV.).	Branches of POSTERIOR TIBIAL including EXTERNAL PLANTAR (to part of plantar aspect of leg and foot, and to digit V. and half of digit IV.).

The comparison of the nerves in the two limbs is more difficult than that of either the bones, the muscles, or the vessels. This depends, partly, upon the fact that nerve-fibres, although they be unlike in office and destination, may nevertheless be bound together in bundles, so as to facilitate their distribution, without, in the slightest degree, interfering with their function. Still we find that the distinctiveness of certain of the groups is preserved. A chief feature of difference, and a great source of difficulty, arise from the circumstance that the nerves to the lower limb pass, in great measure, behind the pelvic arch, the anterior crural nerve only being situate, with the vessels, in front of the pubes; whereas in the upper limb all the nerve-trunks pass, in company with the subclavian artery, behind the scapular arch, and present, therefore, to the vessels and to the scapular arch the same relations as do the anterior crural nerves to the femoral vessels and the pelvic arch. The source of this difference is, partly, explained by the position of the limbs at an early period of fœtal life. The upper limb is, then, in its primitive unfurled condition, and in a plane anterior to the part of the spinal cord, and the vertebral column from which the branches of the brachial plexus are derived; the nerves of that plexus, therefore, (except the suprascapular which preserves an antagonistic relation to the homologous branches of the glutæal nerves,) pass behind the scapular arch to the limb, and are united into one great plexus. The lower limb, on the other hand, is, at first, placed opposite the middle of that tract of the cord and vertebral column from which its nerves are derived, and that tract is of greater length than in the case of the upper limb; the nerves, consequently, are divided into two great plexuses instead of one, and the offsets of the one—the lumbar plexus—pass chiefly in front of the pelvic arch, while those of the other—the sacral plexus—pass behind.

Hence the nerves—the anterior crural—to the *ant*erior part of the thigh are separated from those—the sciatic—which supply the remainder of the same aspect of the limb. Whereas, in the upper limb, all the nerves passing to the corresponding—that is the *post*erior—aspect, and supplying all the extensor muscles of the limb, are grouped together into one trunk—the radial.

Hence also the nerves to the Extensor muscles of the hand, being united in one trunk with those to the Extensor muscles of the elbow, pass, round the ulnar side of the *humerus*, to the dorsal aspect of the limb; whereas the corresponding nerves to the extensor muscles of the foot—the peroneal—being separate from the nerves to the extensors of the knee, continue their course, with the flexor nerves, down the back of the thigh, and not till they have passed the knee do they travel round the *fibula* to the dorsal aspect of the leg.

In the tendency to a homological distribution of the nerves of the foot and hand we see a reason why the internal plantar nerve should be larger, and supply a greater number of digits, than the external plantar nerve, although the reverse is the case with regard to the plantar arteries.

DESCRIPTION OF PLATES.

The Roman numerals, I. II. III. IV. V., refer to the digits commencing from the Pollex.

1. Humerus.
2. Radius.
3. Ulna.
4. Olecranon.
5. Scaphoid.
6. Semilunar.
7. Cuneiform.
8. Pisiform.
9. Trapezium.
10. Trapezoid.
11. Os Magnum.
12. Unciform.
13. Metacarpals.
14. First row of Phalanges.
15. Second row.
16. Third row.
17. Scapula.
    - (*a*) spine.
    - (*b*) posterior costa.
    - (*c*) inferior angle.
    - (*d*) roughness for tendon of triceps.
18. Coracoid.
19. Clavicle.

The numerals with dash, I′. II′. III′. IV′. V′., indicate the digits in the hinder limb.

1′. Femur.
2′. Tibia.
3′. Fibula.
4′. Patella.
5′. Scaphoid.
6′. Astragalus.
7′. Os Calcis.
8′. Hinder part of os calcis.
9′. Internal cuneiform.
10′. Middle do.
11′. External do.
12′. Cuboid.
13′. Metatarsals.
14′. First row of Phalanges.
15′. Second row.
16′. Third row.
17′. Ilium.
    (*a′*) sacral ridge.
    (*b′*) crest.
    (*c′*) anterior superior spine.
    (*d′*) .... inferior do.
18′. Pubes.
19′. Ischium.

PLATE I.

Fig. 1. Human left scapula and upper extremity. *a*, great tubercle of humerus; *s*, spine of scapula; *b*, hinder border; *c*, inferior angle; *d*, point of attachment of long head of triceps extensor cubiti. The lower end of the radius and the carpus are placed at a little distance from the ulna to render them more distinct.

Fig. 2. Human pelvis and left lower extremity; *a′*, great trochanter; *b′*, crest of ilium; *c′*, anterior superior spine; *d′*, anterior inferior spine.

Fig. 3. Diagram of human hand.

Fig. 4. Diagram of human foot.

Fig. 5. Left hind foot of great Kangaroo. (Cambridge Museum.)

Fig. 6. Left knee of Kangaroo Rat, shewing (*s*) the sesamoid bone behind outer condyle of femur.

Fig. 7. Left knee of Bandicoot Opossum (Coll. Surg. Museum), shewing (*s*) the sesamoid placed nearer to upper end of fibula.

Fig. 8. View of inner side of left hind foot of Bandicoot Opossum.

Fig. 9. Right side of Pelvis of Armadillo (Cambridge Museum); *a'*, sacral ridge of ilium; *b'*, crest of ilium; *sc*, sacro-sciatic forearm; *o*, obturator foramen; *a*, acetabulum; *sa*, sacrum; *cv*, caudal vertebræ; *lv*, lumbar vertebræ.

Fig. 10. Thorax and left wing of Apteryx (Coll. Surg. Museum); *dv*, dorsal vertebræ; *r*, ribs; r^a, appendages to ribs; *st*, sternum; *str*, sternal ribs.

PLATE II.

Fig. 1. Fore limb of Elephant (Cambridge Museum); digit v. is not seen.

Fig. 2. ... Hippopotamus. ... ...

Fig. 3. ... Rhinoceros. ... ...

Fig. 4. ... Buffalo. ... ...

Fig. 5. ... Musk-Deer. ... ...

Fig. 6. ... Horse. ... ...

Fig. 7. Hind limb of Elephant. ... ...

Fig. 8. ... Hippopotamus. ... ...

Fig. 9. ... Rhinoceros. ... ...

Fig. 10. ... Buffalo. ... ...

Fig. 11. ... Horse. ... ... The scaphoid, middle, and internal cuneiform are conjoined. The last is not seen.

Fig. 12. Fore limb of Ornithorhynchus Paradoxus (Cambridge Museum), side view.

Fig. 13. Hind limb of Ornithorhynchus Paradoxus. The carpal bones in the preceding, and the tarsal bones in this, are indistinct, in consequence of the soft parts remaining; *s*, expanded upper end of fibula occupying the position of the ossicle (*s*) in following figure of Dasyurus. Compare fig. 20, and Pl. I. figs. 6 and 7.

Fig. 14. Left side of Pelvis, femur, tibia, fibula and sesamoid bone (*s*) of Dasyurus Ursinus (Museum of Coll. of Surgeons); *m*, marsupial bone.

Fig. 15. Left fore foot of the same.

Fig. 16. Left hind foot of the same.

Fig. 17. Hind limb of Seal. (Cambridge Museum.)

Fig. 18. Fore limb of same.

Fig. 19. Front view of fore limb of Ornithorhynchus Paradoxus. (Coll. of Surgeons' Museum.)

Fig. 20. Front view of hind limb of the same with left side of pelvis; *m*, marsupial bone; *s*, expanded upper end of Fibula corresponding with ossicle in fig. 14.

Fig. 21. Fore limb of Bradypus tridactylus. (Cambridge Museum.)

Fig. 22. Hind limb of ditto. There are only two phalanges (14 and 16 and 14′ and 16′) in each digit of the fore and of the hind limb. The representatives of digits I. and V. and I′. and V′. are merely outgrowths from the proximal ends of the adjacent metacarpals (13) and metatarsals (13′). The second row of the tarsus (11′ and 12′) are ankylosed together and to the heads of the metatarsals.

Fig. 23. Fore limb of Tortoise (Cambridge Museum). The Scaphoid (5) as well as the Unciform (12) is in two pieces.

Fig. 24. Fore limb of Iguana (Cambridge Museum). Digit III. has four and digit IV. has five phalanges. The Unciform (12) is in two pieces.

Fig. 25. Fore limb of Tortoise (Cambridge Museum). The trapezium and trapezoid (9 and 10) are joined, and the scaphoid extends beneath the lunar.

Fig. 26. Fin of Bottle-nosed Whale. (Coll. of Surgeons' Museum.)

Fig. 27. Right hind limb of Hyæna (Cambridge Museum); view of outer side.

Fig. 28. Right fore limb of Hyæna; view of outer side.

Fig. 29. Front view of right hind limb of same.

Fig. 30. Front view of right fore limb of same.

Fig. 31. Fore limb of Turtle. (Cambridge Museum.)

Fig. 32. Fore limb of Crocodile. The bones of the distal carpal row are blended together. There are four phalanges in digit III.; one of these is numbered 17.

Fig. 34. Fore limb of Ostrich. (Cambridge Museum.) The representatives of the os magnum, the cuneiform bone and the three metacarpals are united together.

Fig. 35. Hind limb of ditto; *t*, the tarsal and metatarsal bones united into one long bone.

Fig. 36. Fore limb of Bear. (Cambridge Museum.)

Fig. 37. Fore limb of Hog. (Coll. of Surgeons' Museum.)

Fig. 38. Fore limb of Tapirus Indicus. (Coll. of Surgeons' Museum.)

Fig. 39. Hind limb of ditto.

PLATE III.

Fig. 1. Skeleton of a Perch (Cambridge Museum). *PF*, pectoral fin; *VF*, ventral fin; *AF*, anal fin; *DF*, dorsal fin; *CF*, caudal fin; *H*, Hyoidean arch. Behind this is the scapular arch composed of three pieces, of which the upper, or supra-scapula (*SS*), is attached to the occipital bone; the middle piece (17) is the scapula; the lower piece, or coracoid (18), completes the arch beneath. To it is attached the pectoral fin by the radius (2) and the ulna (3); *rr*, ribs.

Fig. 2. Scapular arch and pectoral fin of Cod-fish (Cambridge Museum). *SS*, supra-scapula; *c*, carpal bones.

Fig. 3. Pelvis and ventral fin of same.

Fig. 4. Skeleton of Alligator (Cambridge Museum). *S*, sternum; *r*, rib; *cr*, cervical rib; *h*, hæmal bones, or sternal ribs; *lh*, lateral hæmal bones, or lateral sternal ribs. The proximal row of carpal bones consists of one large scapho-lunar bone (5 and 6) and a cuneiform (7). The distal row are united together. Digit III. contains four phalanges. In the tarsus the scaphoid and astragalus (5′, 6′) are conjoined, and the distal row (*t*) is represented by one small bone. Digit V′. consists of one small bone; digit I′. consists of the usual number of bones; the other three digits are complete.

Fig. 5. Side view of under surface of Alligator's trunk (Cambridge Museum). It shews the disposition of the hæmal bones or sternal ribs (*h*), and of the lateral hæmal bones or lateral sternal ribs (*lh*), and their relation to the components of the scapular (17 and 18) and the pelvic (17′, 18′, 19′) arches. *r*, rib; *v*, body of vertebra; *t*, transverse process; *S*, sternum.

Fig. 6. Fore and hinder parts of skeleton of Scincus (Cambridge Museum). The letters and numerals indicate the same as in preceding figures. There are three phalanges in Digit I. of the fore limb, four in Digit II. and in III., three in Digit IV., and two in Digit V. In the hind limb there are two in Digit I′., three in Digit II′., four in Digit III′. and in IV′., three in Digit V′.

Fig. 7. Trunk and limbs of Plesiosaurus. *cr*, cervical rib.

Fig. 8. Pelvis and hind limb of Ichthyosaurus.

Fig. 9. Scapular arch and fore limb of Ichthyosaurus.

The last three are from drawings kindly lent by Professor Sedgwick.

Fig. 10. View of skeleton of Turtle from beneath (Cambridge Museum).

Fig. 11. Scapular arch and sternum of Bull-frog (College of Surgeons' Museum). *S*, sternum; *ES*, episternum; *SS*, supra-scapula; *g*, glenoid cavity.

Fig. 12. Fore and hinder parts of skeleton of Menopoma (Cambridge Museum).

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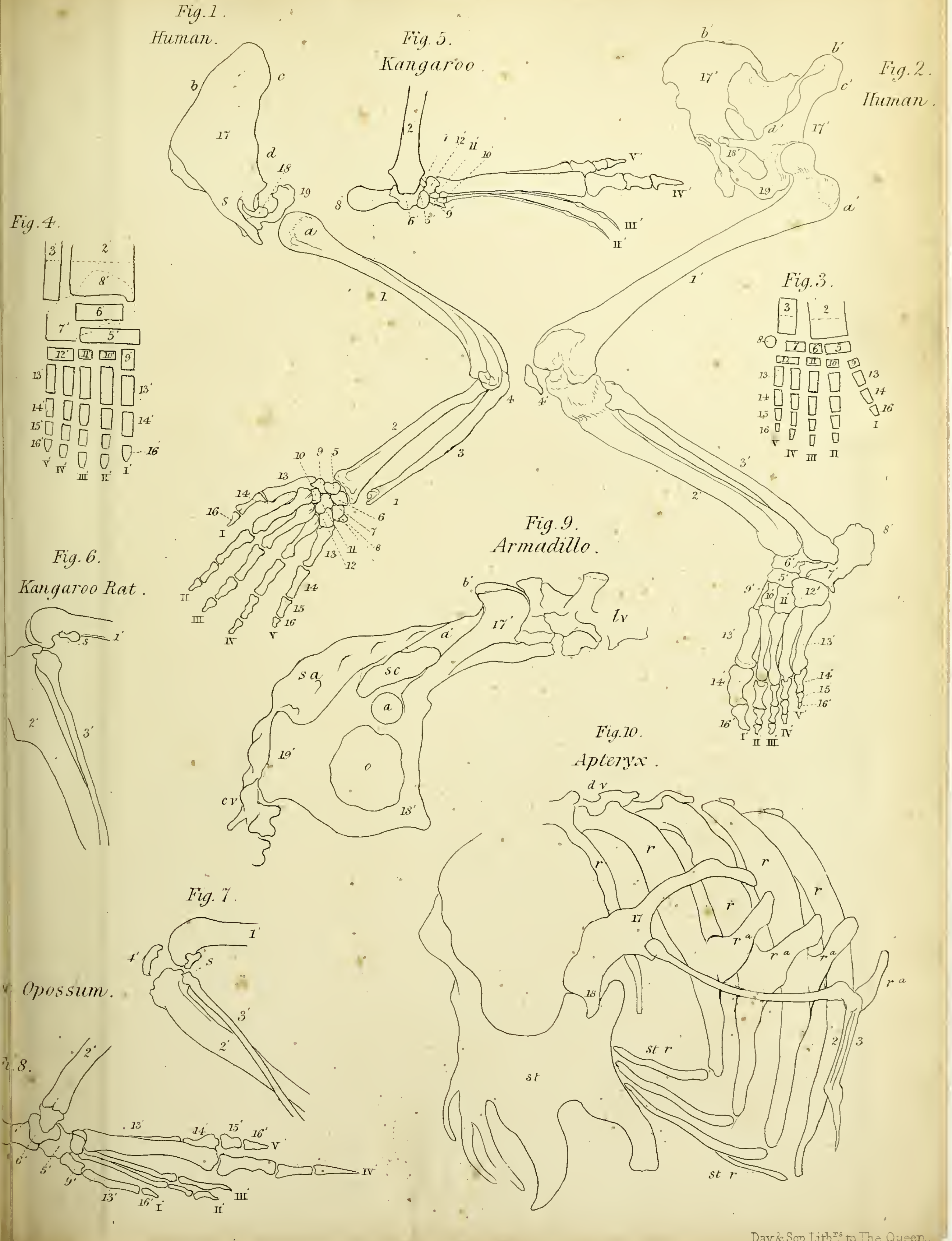
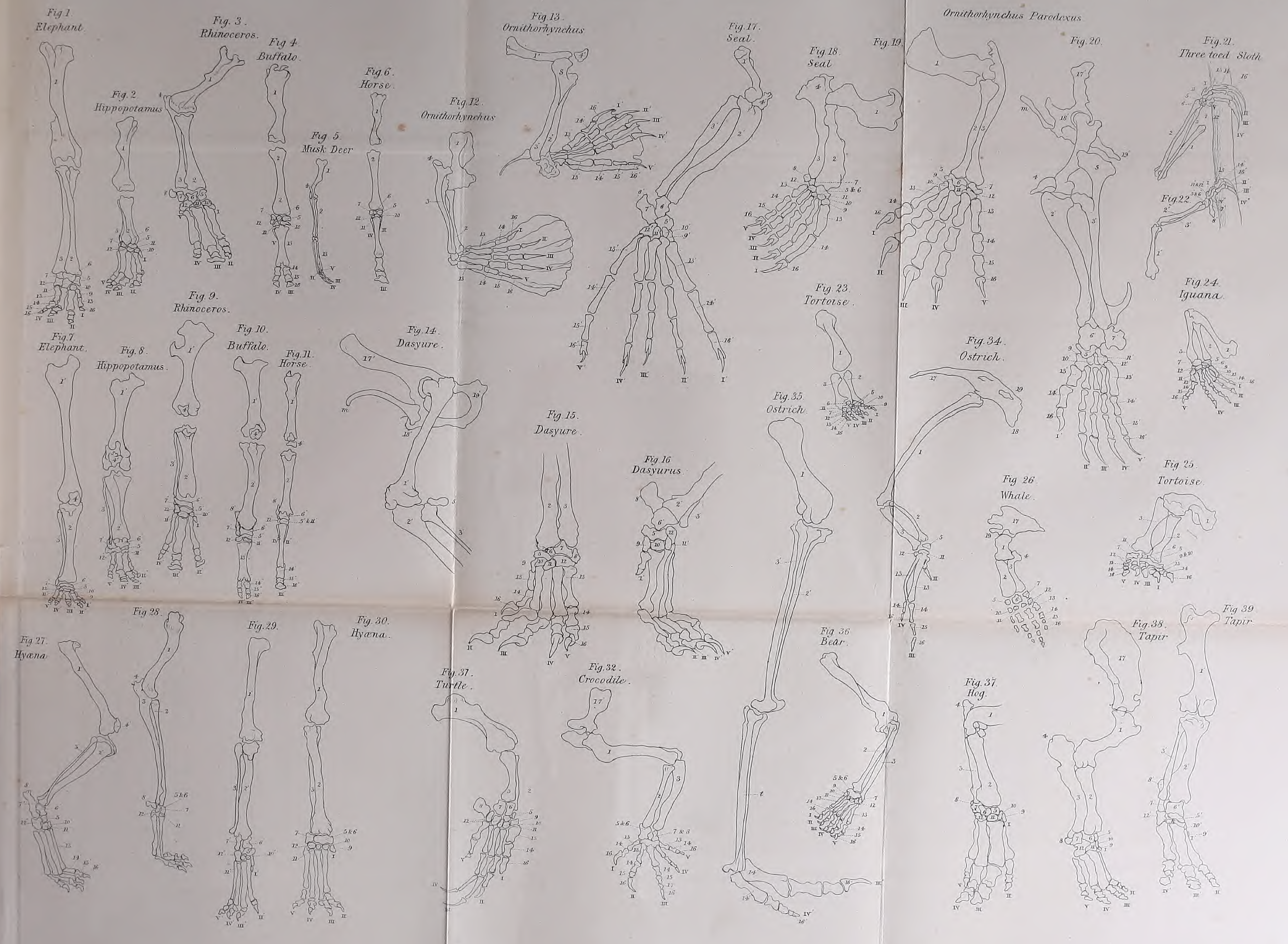
PLATE 1.



Day & Son, Lith.rs to The Queen.

PLATE II.



Day & Son. Lith^rs to The Queen.

PLATE III.

Day & Son, lith^rs to The Queen.